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FOUNDATION BRAKE RIGGING
AIR-SIGNAL SYSTEM
PC PASSENGER BRAKE EQUIPMENT
PM AND LN PASSENGER BRAKE EQUIPMENT
TYPE K FREIGHT TRIPLE VALVE
TRAIN CONTROL

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the non-essentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed. At the end of the volume will be found a complete index, so that any subject treated can be quickly found.

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CONTENTS

KEY TO THE COLOR PLATES

RED	*Main-Reservoir Pressure*
PINK	*Brake-Cylinder Pressure*
GREEN	*Auxiliary-Reservoir Pressure*
BLUE GREEN	*Feed-Valve-Pipe Pressure*
LIGHT GREEN	*Equalizing-Reservoir Pressure*
ORANGE	*Atmospheric Pressure*
YELLOW	*Brake-Pipe Pressure*
BLUE	*Live Steam*
LIGHT BLUE	*Exhaust Steam*
PURPLE	*Application-Chamber Pressure* *Supplementary-Reservoir Pressure*
GRAY	*Feed-Valve-Pipe Pressure*
BROWN	*Low-Pressure Air-Cylinder Pressure*
LAVENDER	*Signal-Pipe Pressure*

FOUNDATION BRAKE RIGGING

(PART 1)

ACTION AND CALCULATION OF BRAKE-RIGGING FORCES

LEVERS

DESCRIPTION AND CALCULATION

1. Definition.—A **lever** may be defined as any bar that is capable of being turned about a fixed point. The advantage of a lever is that it forms a convenient means of increasing or decreasing the action of an applied force. Thus, a lever may be used when required to transmit a force that is in excess of an applied force, or a lever may be employed when the applied force is too great and it is necessary to transmit a lesser force. Moving a heavy object by the use of a bar or drawing a nail from a board with a hammer are both common examples of an applied force that is increased by a single lever.

Another example of the increase of force by levers is found in the foundation brake rigging of a car. The pressure required to force the brake shoes against the wheels of a car is a great deal more than the force that can be developed by the compressed air in the brake cylinder, because the size of the brake cylinder that can be used is limited. However, by the use of a system of levers, the force that is exerted in the brake cylinder is increased to such an extent that the brake shoes are forced against the wheels with the pressure required.

2. Action of a Lever.—The manner in which an iron bar is commonly used as a lever is shown in Fig. 1. The end of the bar is placed under the object to be moved, and a block is placed as near as possible to the same end. The object is then moved by applying force to the other end of the bar.

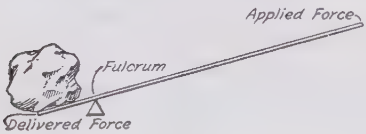


FIG. 1

The force that is applied to the lever is called the *applied force,* the force that is transmitted or delivered to the object to be moved is called the *delivered force,* and the point on which the lever turns is known as the *fulcrum.*

The point at which the force is applied and delivered, and the fulcrum point separate the lever into two parts, and these parts will be referred to as the *distance between the applied force and the fulcrum,* and the *distance between the delivered force and the fulcrum.*

The study of levers involves a consideration of the applied force, the delivered force, the force at the fulcrum, and the length of the lever between the points at which the forces act.

3. Arrangement of a Lever.—A bar can be used as a lever in three different ways, according to the relative positions of the applied force, the delivered force, and the fulcrum. The three different arrangements of levers are shown in Figs. 2, 3, and 4.

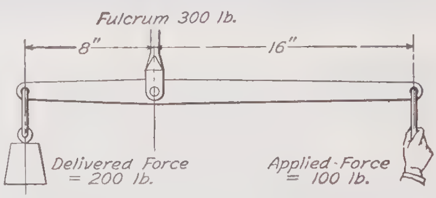


FIG. 2

In Fig. 2 the force is applied at one end of the lever, the force is delivered at the other end, and the fulcrum is between the ends.

In Fig. 3 the force is applied at one end, the fulcrum is at the other end, and the force is delivered between the ends.

In Fig. 4 the force is delivered at one end, the fulcrum is at the other end, and the force is applied between the ends.

4. Increase or Decrease of Force Dependent on Lever Arrangement.—Whether a lever will increase or decrease the force that is applied to it will depend on its arrangement or on the position of the points at which the force is applied and delivered, and the fulcrum. The force which is delivered is always more than the force which is applied when the length of the lever between the applied force and the fulcrum is greater than the length between the delivered force and the fulcrum. The more the first length exceeds the second length, the greater will be the difference between the forces. Thus, in Fig. 2, the long arm of the lever is between the applied force and the fulcrum, and an applied force of 100 pounds delivers a force of 200 pounds.

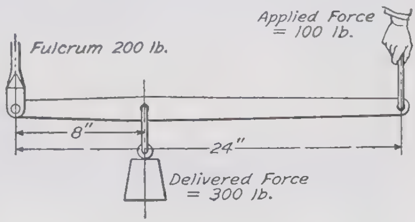


Fig. 3

With the lever arranged as in Fig. 3 the length between the applied force and the fulcrum is the whole length of the lever and cannot be less than the length between the fulcrum and the delivered force. Therefore, with this arrangement the delivered force is always more than the applied force. With this lever an applied force of 100 pounds delivers a force of 300 pounds.

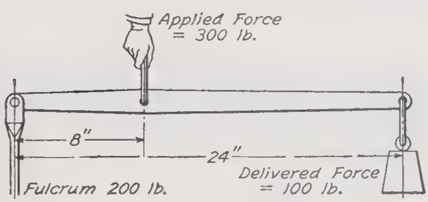


Fig. 4

When the length of the lever between the applied force and the fulcrum is less than the length between the delivered force and the fulcrum, the force delivered will be less than the force applied. This is shown in Fig. 4, in which the length of the lever between the delivered force and the fulcrum is 24 inches, and the length between the applied force and the fulcrum is 8 inches. With this arrangement an applied force of 300 pounds delivers a force of only 100 pounds.

With the lever shown in Fig. 4 the delivered force is always

less than the applied force, because the length of the lever between the fulcrum and the delivered force is the whole length of the lever and cannot be less than the length between the fulcrum and the applied force.

The lever shown in Fig. 2 can also be arranged to deliver a force which is less than the force which is applied to it. If the fulcrum point is moved until it is within 8 inches of the applied force, as in Fig. 5, the delivered force will be at the long end of the lever, and an applied force of 200 pounds will deliver a force of only 100 pounds.

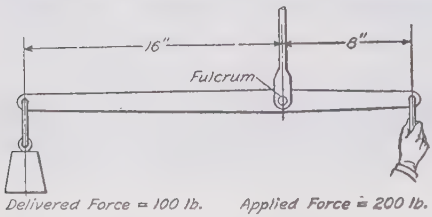


Fig. 5

The arrangement of levers shown in Figs. 4 and 5 are used in foundation brake rigging when it becomes necessary to reduce an applied force which is too great.

5. Distance Moved by Applied and Delivered Forces.—Whenever the applied force is less than the delivered force, the point at which the force is applied always moves farther than the point at which the force is delivered.

In Fig. 6 an applied force of 1 pound delivers a force of 9 pounds. When the end *a* moves from *a* to *a*′, or 1 inch, the end *b* moves from *b* to *b*′, or 9 inches. The difference in the movement of the two ends of the lever is evident, because if an applied force of 1 pound delivers a force of 9 pounds, the distance *bc* must necessarily be nine times as long as the distance *ac*.

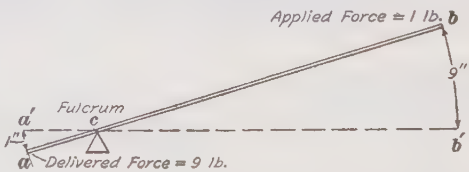


Fig. 6

In Fig. 7 if it is assumed that it is required to deliver to the car wheel a force eight times greater than the force which can be applied by the compressed air in the brake cylinder, the piston in the brake cylinder will have to move 8 inches

in order to move the brake shoe 1 inch, or the piston moves eight times as far as the brake shoe.

Therefore, when a lever delivers a force in excess of the force which is applied to it, the distance which is moved by the applied force in excess of the delivered force will depend on how much the lever multiplies the applied force.

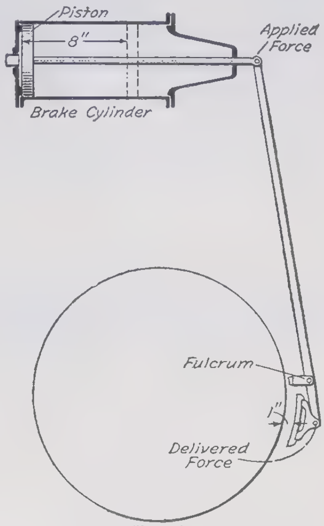


FIG. 7

CALCULATIONS INVOLVING SINGLE LEVERS

6. Forces on a Lever. The forces which act on a lever may be determined by the following rule:

Rule I.—*To obtain the force on a point between the ends of a lever, add together the forces on the ends. To obtain the force at one end, subtract the force at the other end from the force between the ends.*

Figs. 3 and 4 show that the sum of the forces on the ends of a lever is equal to the force between the ends. These figures also show that subtracting the force at one end from the force between the ends gives the force on the other end.

7. Lever Calculations.—Lever calculations are those which are necessary to determine the applied force, the delivered force, and the length of the lever between the applied force and the fulcrum, and between the delivered force and the fulcrum. It is necessary that three of these terms be given before the other one can be found. Certain problems in levers also require that the fulcrum point be located.

8. General Rule for Calculating Levers.—The general rule for calculating levers is as follows:

Rule.—*The applied force multiplied by the length of the lever between the applied force and the fulcrum is equal to the delivered force multiplied by the length of the lever between the delivered force and the fulcrum.*

From this the following rules can be deduced for calculating levers:

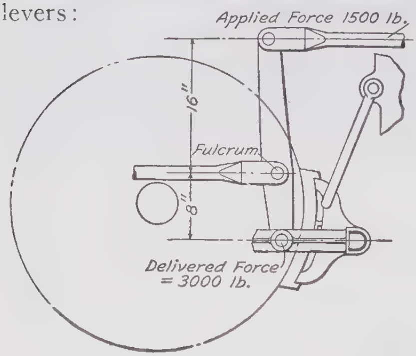


Fig. 8

Rule II.—*To find the delivered force, multiply the applied force by the length of the lever between the applied force and the fulcrum, and divide by the length of the lever between the delivered force and the fulcrum.*

Example.—In Fig. 8 a force of 1,500 pounds is applied to the upper end of the lever; what is the delivered force with the lever dimensions as shown?

Solution.—From rule II, the delivered force is equal to

$$\frac{1{,}500 \times 16}{8} = 3{,}000 \text{ lb. Ans.}$$

Rule III.—*To find the applied force, multiply the delivered force by the length of the lever between the delivered force and the fulcrum, and divide by the length of the lever between the applied force and the fulcrum.*

Example.—In Fig. 9 the force delivered is 3,000 pounds and the lever dimensions are as shown; what force is applied to the lever?

Solution.—From rule III, the force applied to the lever is equal to

$$\frac{3{,}000 \times 8}{24} = 1{,}000 \text{ lb. Ans.}$$

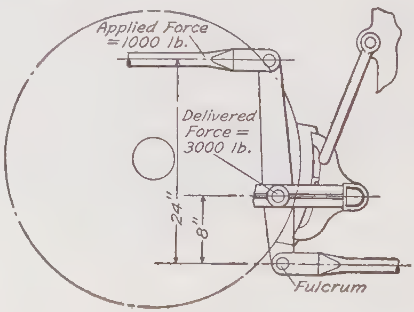


Fig. 9

Rule IV, which follows, is used when it becomes necessary

to find how far the fulcrum point is from the ends of a lever when the total length of the lever and the applied and delivered forces are known. This problem is met with only when the lever is arranged as shown in Fig. 2, because with the other two arrangements, as shown in Figs. 3 and 4, the fulcrum point is at the end of the lever.

Rule IV.—*To find the length of the lever between the fulcrum and the applied force, multiply the delivered force by the total length of the lever and divide by the sum of the applied and delivered forces.*

To find the length of the lever between the delivered force and the fulcrum, multiply the applied force by the length of the lever and divide by the sum of the applied and delivered forces.

Example.—The total length of a lever is 30 inches. The applied force is 300 pounds and the delivered force is 700 pounds. How far is the fulcrum from the applied and the delivered forces?

Solution.—From rule IV, the length of the lever between the fulcrum and the applied force is equal to

$$\frac{700\times30}{300+700}=21 \text{ in. Ans.}$$

The length of the other end of the lever is then 30−21, or 9 inches. However, the length of the other end can be found by applying rule IV. Thus,

$$\frac{300\times30}{300+700}=9 \text{ in. Ans.}$$

Rule V.—*To find the length of the lever between the applied force and the fulcrum, multiply the delivered force by the length of the lever between the delivered force and the fulcrum, and divide by the applied force.*

Example.—In Fig. 10 find the length of the lever between the applied force and the fulcrum with the other lever terms as shown.

Solution.—From rule V, the length of the lever between the applied force and the fulcrum is equal to

$$\frac{1{,}500\times24}{3{,}000}=12 \text{ in. Ans.}$$

Rule VI.—*To find the length of the lever between the delivered force and the fulcrum, multiply the applied force by the length of the lever between the applied force and the fulcrum and divide by the delivered force.*

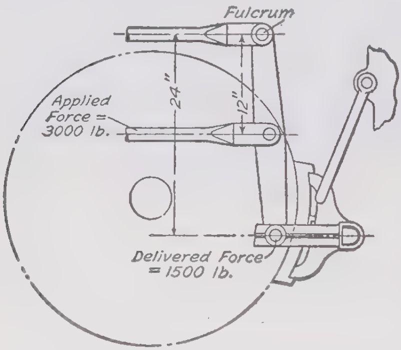


FIG. 10

EXAMPLE.—How can the length of the lever between the delivered force and the fulcrum as shown in Fig. 10 be obtained?

SOLUTION.—From rule VI, the length of the lever between the delivered force and the fulcrum is equal to

$$\frac{3{,}000 \times 12}{1{,}500} = 24 \text{ in.} \quad \text{Ans.}$$

9. Calculating Levers Without Use of Rules.—In many cases the calculations that relate to levers may be performed mentally, and the rules do not always have to be used. By comparing the length of the lever between the applied and delivered forces and the fulcrum, the amount that the applied force is increased or decreased may be calculated quickly.

In Fig. 8 the part of the lever between the applied force and the fulcrum is twice as long as the other part; therefore, the lever must transmit 2 pounds of force for every pound of force that is applied. An applied force of 1,500 pounds, then, delivers a force of 3,000 pounds.

In Fig. 9 the length of the lever between the applied force and the fulcrum is three times as long as the part of the lever between the delivered force and the fulcrum. Each pound of applied force, therefore, delivers a force of 3 pounds, or 1,000 pounds transmits 3,000 pounds.

In Fig. 10 the length of the lever between the applied force and the fulcrum is one-half as long as the part between the delivered force and the fulcrum. Each pound of force that is applied will deliver only one-half a pound of force, or the delivered force will be one-half of the applied force.

FRICTION

DEFINITION AND THEORY

10. Definition of Friction.—A block of wood when moved over a table resists movement and a certain amount of effort is required to keep it moving after it has been started.

The resistance to movement that is encountered when one body is moved over another is called friction.

11. Theory of Friction.—The theory of friction is as follows: The surface of any material, no matter how highly it is polished, is made up of minute hills and hollows. If these elevations and depressions can be seen or felt, the surfaces are said to be *rough,* but if not the surfaces are said to be *smooth.*

When two bodies *a* and *b,* Fig. 11, are placed in contact, the inequalities on their surfaces tend to interlock, as shown. Therefore, when *a* is moved over *b* the interlocking, or meshing, action of the irregularities in the two surfaces results in a resistance to movement that is called *friction.* The greater the weight of *a* or the greater the force with which *a* is pressed against *b,* the more firmly the irregularities in the two surfaces will interlock and the greater will be the friction. The friction between two surfaces, then, depends on the condition of the surfaces and the force that is pressing them together.

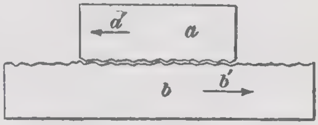


FIG. 11

It will be noted that as friction resists motion, frictional resistance will act in a direction opposite to motion when a body is moving. Thus, in Fig. 11, *a* is being moved to the left by a pull which is in the direction of the arrow *a'*. The friction between *a* and *b* causes *b* to set up a pull that acts in the direction of the arrow *b'*, and which is equal to the pull in the direction *a'*. A pull in one direction is always resisted by an equal pull in the opposite direction. This point has an important bearing on brake-shoe friction and rail friction, to be described later.

KINDS OF FRICTION

12. There are two kinds of friction: *static* and *kinetic,* and the difference between them may be more easily understood by reference to Fig. 11. If it is assumed that the pull on *a* is just enough to start this body moving from a state of rest, the friction to be overcome in starting the body is called *static friction,* or *friction of rest.* If the pull on the body is maintained, and *a* is caused to slide over *b,* the friction that is overcome is now called *kinetic friction,* or *friction of motion.*

Less effort is required to keep a body moving than to start it moving. In other words, kinetic friction is always less than static friction. The explanation is that when a body is at rest the elevations and depressions in the two surfaces have a chance to become more or less thoroughly interlocked and considerable effort is required to pull one surface free from the other. However, as soon as one body is started the elevations on one surface do not have time to fit into the depressions on the other surface, and the resistance to movement decreases.

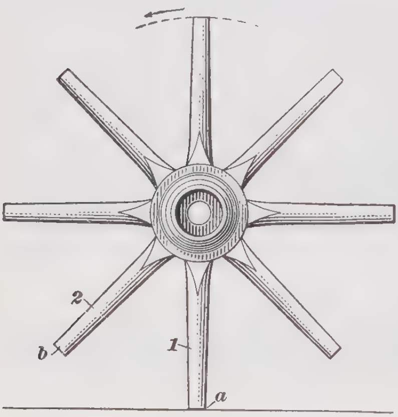


FIG. 12

13. Rolling Motion and Rolling Friction.—To understand what is meant by rolling friction, it is necessary to consider, briefly, rolling motion. Fig. 12 shows a wheel without the tire. If the wheel is turned the motion is not exactly rolling, but rather a series of rotations about the ends of the spokes as they come in contact with the ground. Thus, as shown, the entire wheel is rotating about the end *a* of the spoke *1*, but in the next instant the rotation will be about the end *b* of the spoke *2*.

For an instant, then, the end of the spoke on the ground is

not moving but is at rest, and the whole wheel turns about the point that is at rest. If the number of spokes were multiplied a great many times, the wheel would roll smoothly over the ground, but the character of the motion would remain the same; that is, for each instant there would be no movement between the ground and the end of the spokes.

When a tire is applied to the wheel, it is not difficult to imagine the tire as being made up of a great number of spokes which are placed very closely together. Then, for an instant, the part of the tire in contact with the ground is at rest with respect to the ground, and the wheel is rotating as a whole about the point in contact. The photograph of a wheel rolling on a rail shows the part of the wheel near the rail clearly and sharply defined, while the upper part of the wheel is blurred. This is an indication that the part of the wheel which is in contact with the rail is at rest relatively to the camera. Therefore, the friction between the part of a car wheel that is resting on a rail is friction of rest and not friction of motion. Instead of referring to this friction as static friction, it is called *rolling friction,* on account of the rolling motion of the body.

Rolling friction is, therefore, another name for static friction, and this term will be used with the meaning of static friction when the friction between a wheel and a rail is considered.

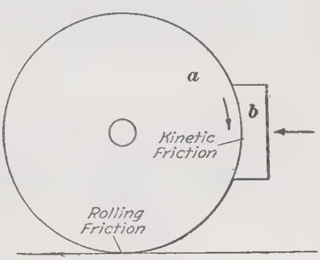


Fig. 13

14. Rolling and Kinetic Friction Acting in Opposition.—A brake shoe when it is applied to a revolving car wheel furnishes an example of rolling and kinetic friction acting in opposition. In Fig. 13 if we assume that the wheel shown is turning on the rail in the direction indicated by the arrow, the friction between the wheel and the rail is rolling friction.

The friction between the brake shoe *b* and the wheel will be considered next. When the brake is applied, the friction between these parts is kinetic friction, or the friction of motion,

because the wheel is turning against the stationary shoe. The brake shoe may be compared to b in Fig. 11, and the wheel to a. Therefore, the rolling friction between the wheel and the rail tends to keep the wheel turning and acts in opposition to the kinetic friction between the brake shoe and the wheel, which tends to stop the wheel from turning. The rolling friction between the wheel and the rail is called *adhesion*, when the maximum friction between these parts is meant.

FRICTION PRODUCED BY BRAKES

15. How Friction Stops a Train.—A *brake* is a device that depends on friction to stop or retard motion. The friction that results from the application of the brake shoes to the wheels is usually regarded as being the sole factor in stopping a train. However, it will now be shown that another factor must receive consideration.

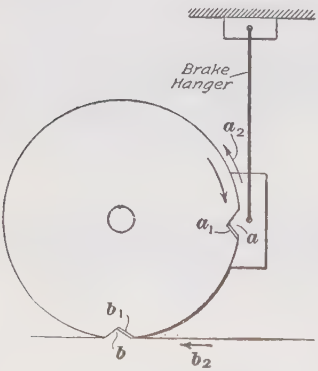


Fig. 14

It has already been mentioned in Art. **11** that friction always acts to set up an equal pull in the direction opposite to the pull that produces motion. The operation of this action on a car wheel will be explained by considering Fig. 14. This figure shows a car wheel which is assumed to be moving in the direction shown by the arrow on the wheel.

The pull that is necessary to keep the wheel turning causes the part of the wheel in contact with the rail to exert an equal backward push on the rail. In other words, the wheel pushes backward on the rail with the same force that the wheel is pulled ahead. It will now be shown how the above condition changes when the brake is applied.

It is assumed in Fig. 14 that the total friction between the brake shoe and the wheel is equal to that which is produced

by the elevation a on the shoe when it interlocks with the depression a_1 in the wheel; likewise the friction between the wheel and the rail is equal to the friction that results from the interlocking of b and b_1. When the elevation a interlocks with the depression a_1, the friction produces a pull on the wheel that tends to stop it from turning. The direction of this pull is shown by the arrow a_2. When a interlocks with a_1, the depression b_1 on the wheel is forced against the elevation b on the rail. The resulting friction causes the wheel to push forward against the rail, or the rail to push backward against the wheel with a force equal to the pull of the brake shoe on the wheel. The direction of this backward push is shown by the arrow b_2. Therefore, the retarding force that acts on a train to stop it is the friction between the wheels and the rails or the rail pull, and this friction or pull is caused by and is equal to the friction between the brake shoes and the wheels.

When trains are being stopped the friction that causes the push backward on the wheel is generally referred to as *rail pull,* and the friction between the brake shoe and the wheel as *wheel pull.* When these terms are used, the force that stops a train is the rail pull, which is equal to the wheel pull or the pull or push on the brake hangers. There would be a pull on the brake hangers when the brake shoe is hung as in Fig. 14. However, there would be a push on the hanger with the brake shoe behind the wheel, and the wheel turning in the same direction, as in Fig. 14.

16. The rail friction is in reality a more important factor than the brake-shoe friction, because the brake-shoe friction is limited by the rail friction. It would be useless to have more brake-shoe friction than rail friction, because the wheels would slide as soon as the brakes were applied.

The importance of rail friction in the stopping of a train may be more easily understood by considering the rails as being greased or made of some material that offers little friction such as ice. The brakes would apply with their usual pressure, but because of the absence of rail friction the wheels would immediately slide and very little resistance would be

offered to stop them. Therefore, if it were not for the rail friction, the friction which is developed by the brake shoes would be of no effect.

COEFFICIENT OF FRICTION

17. The meaning of the term *coefficient of friction* as applied to the air brake will be explained by considering Fig. 15. This figure shows a brake shoe connected to a spring balance by a hanger. The wheel is assumed to be turning in the direction of the arrow and it is also assumed that the brake shoe is being pressed against the wheel with a constant pressure of 1,000 pounds. The friction between the surfaces of the brake shoe and the wheel causes a downward pull on the shoe, and this pull is communicated to the spring balance through the hanger. If it is assumed that the pull registered by the spring balance is 100 pounds, the friction between the brake shoe and the wheel is 100 pounds, or 100 pounds of the 1,000 pounds brake-shoe pressure acts as friction to stop the rotation of the wheel.

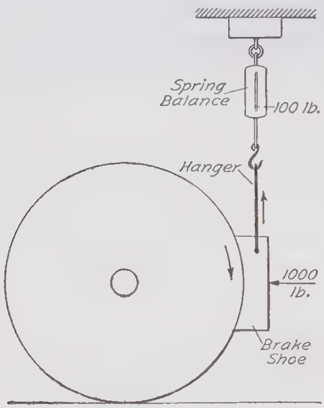


Fig. 15

Instead of saying that so much friction is obtained from some certain pressure, it is convenient to use a term that will indicate the friction that results from each 100 pounds of pressure. This makes it necessary to compare the brake-shoe friction with the brake-shoe pressure. The comparison is made by dividing the friction by the pressure. Thus $\frac{100}{1000} = \frac{1}{10}$, or 10 per cent., and the friction is, therefore, 10 per cent. of the brake-shoe pressure. The comparison between the brake-shoe friction and the brake-shoe pressure expressed as per cent. is called the coefficient of friction.

The coefficient of friction in the preceding example is 10 per cent., because a comparison between the friction and the

pressure shows that the former is 10 per cent. of the latter. A coefficient of friction of 10 per cent. then, means that each 100 pounds of brake-shoe pressure gives a brake-shoe friction of 10 pounds. In other words, a force of 10 pounds acts to stop the wheel from turning for each 100 pounds of force that is applied to the brake shoes.

It is important to know what the coefficient of friction is, because when its value is given, it is a simple matter to find the brake-shoe friction when the brake-shoe pressure is given. It is the practice in the solution of air-brake calculations to express a per cent. as a decimal, thus: 10, 15, or 25 per cent. is written as .10, .15, or .25.

18. Rule for Finding the Coefficient of Friction. To find the coefficient of brake-shoe friction, it is necessary to ascertain what per cent. of the brake-shoe pressure the brake-shoe friction is. This can be done by the use of the following rule:

Rule.—*To find the coefficient of friction, multiply the brake-shoe friction by 100, and divide by the brake-shoe pressure.*

EXAMPLE.—The brake-shoe friction, as indicated by the pull on the brake-beam hangers, is 500 pounds, and the brake-shoe pressure is 2,500 pounds. What is the coefficient of friction?

SOLUTION.—From the rule, the coefficient of friction is

$$\frac{500 \times 100}{2{,}500} = 20 \text{ per cent. Ans.}$$

19. Distinction Between Friction and Coefficient of Friction.—A distinction should be made between the terms *brake-shoe friction* and *coefficient of brake-shoe friction,* and care should be taken not to confuse their meaning. It is correct to use the term brake-shoe friction when it is not desired to show the comparison between it and brake-shoe pressure; thus, it can be said that brake-shoe friction is the result of brake-shoe pressure.

The term coefficient of friction is to be used when it is desired to compare or to show the relation between brake-shoe friction and brake-shoe pressure. Thus the statement

that the coefficient of friction is 10 per cent., means that the brake-shoe friction is $\frac{1}{10}$ or 10 per cent. of the brake-shoe pressure, or that the pressure is ten times greater than the friction.

20. Rule for Finding the Brake-Shoe Friction. The friction between the brake shoe and the wheel is equal to the pull or the push in pounds on the brake-beam hanger. When it is required to find the brake-shoe friction, it is necessary to multiply the brake-shoe pressure by the coefficient of friction. The brake-shoe friction can then be determined from the following rule:

Rule.—*To find the brake-shoe friction, multiply the brake-shoe pressure by the coefficient of friction.*

EXAMPLE.—The brake-shoe pressure is 6,000 pounds, and the coefficient of friction is 15 per cent. or .15. What is the friction that acts to stop the rotation of the wheel?

SOLUTION.—From the rule, the friction equals $6{,}000 \times .15 = 900$ lb. Ans.

The brake-shoe friction is always much less than the brake-shoe pressure. This is shown by the size of the brake levers, pins, and brake beams through which the brake-shoe pressure is transmitted as compared with the size of the brake-beam hangers which resist the pull which results from the brake-shoe friction.

21. Conditions Affecting the Coefficient of Friction.—The coefficient of friction is affected by and depends on: (*a*) the pressure with which the brake shoes are forced against the wheels; and (*b*) on the condition of the surfaces of the brake shoes and the wheels that engage. If the brake-shoe pressure is maintained constant, any change in the coefficient of friction must be due to a condition that affects the surfaces in contact. The application of the brake shoes to the wheels when stopping a fast, heavy train causes the shoes to become very hot. Therefore, the heating of the brake-shoe metal that is opposed to the wheels is the sole cause of the change in the coefficient of friction. The temperature of a brake shoe depends on the pressure against it, the speed of the wheel, and the time the shoe is in contact with it.

22. Variation in Coefficient of Friction During a Stop.—When a variation in the coefficient of friction is considered, it will be assumed that a stop is being made with a modern fast passenger train. The coefficient of friction varies throughout the stop, and it is very difficult to determine its exact value on account of the rapid changes in the temperature of the surfaces of the brake shoes. When the brakes are first applied the coefficient of friction increases, then it decreases and remains fairly constant, and, as the speed decreases to about 30 miles per hour, it begins to increase again and continues to do so until the train stops. The reason for this variation is as follows: When the brakes are applied the heating of the brake shoes causes the coefficient of friction to increase, and it is estimated that it reaches its maximum when the temperature of the rubbing surfaces reaches about 800° F. As the temperature goes higher, the metal in the brake shoes becomes so hot that it begins to weaken, and, under severe conditions, it may even discharge from the brake shoes in a molten condition. The coefficient of friction decreases at this time because the elevations in the surfaces that are in contact are more easily rubbed off. The coefficient of friction then remains fairly constant even with the rubbing surfaces in a molten condition because, as the metal weakens or is thrown off, a new surface is presented to the wheel, which breaks down in turn and causes another surface to be set up. As the speed reduces the slower rotation of the wheels permits the brake shoes to cool off, until the metal in the shoes is no longer thrown off or has its abrasive qualities weakened by heat. As the brake-shoe metal returns to its normal condition the coefficient of friction will keep increasing until the stop is completed.

23. When a high braking force is used to stop a train at a relatively low speed, the coefficient of friction increases from the time the brakes are applied until the train stops; the reason is that the surfaces in contact do not become so hot and this results in a better interlocking of the brake shoe and wheel metal. The fact that the coefficient of friction is greater at

low than at high speed explains why such severe shocks result from heavy brake applications and why wheels will slide at low speed and not at high speed.

It must be remembered that the coefficient of friction is a measure of the retarding action of the brake shoes. Therefore, in the foregoing when the coefficient of friction is low, the retarding action of the brakes is also reduced, and the opposite occurs when the coefficient of friction increases. The reason that the brake shoes wear out so rapidly under severe braking conditions without affecting the wheels, is on account of the harder and tougher nature of the wheel, and because the surface of the wheel is not continuously in contact with the brake shoe, while the brake shoe is in continuous contact with the wheel.

24. Mean Coefficient of Friction.—As already stated, the coefficient of friction is constantly changing while the train is being stopped, and it is very difficult to determine its value at any one time. However, tests have shown that the mean or average coefficient of friction, when a stop is made with a modern passenger train, is approximately 10 per cent. In freight service the average coefficient of friction is considerably higher and may run as high as 15 or 18 per cent.

The statement that the mean coefficient of friction is 10 per cent. emphasizes the small amount of friction or retarding force that is actually developed by the brake shoes. The statement will have more significance when it is stated that only 1 pound acts as friction for each 10 pounds of brake-shoe pressure. This means that the efficiency of the brake shoes is only 10 per cent.

ADHESION

25. Coefficient of Adhesion.—It has already been explained that the friction between the wheels and the rail causes the wheels to turn when the car is being moved. This friction is termed *rolling friction* and the term *adhesion* refers to the maximum rolling friction between the wheel and the rail.

The term *coefficient of adhesion* will be explained by considering a wheel weighing 1,500 pounds. If the maximum fric-

tion or adhesion between the wheel and the rail is 375 pounds, it would require a brake-shoe friction of this amount to slide the wheel. A comparison between 375 and 1,500 shows that the former is $\frac{1}{4}$, or 25 per cent. of the latter. Thus, $\frac{375}{1500} = \frac{1}{4}$, .25, or 25 per cent.

The term coefficient of adhesion is applied to the comparison between the adhesion between the wheel and the rail, and the weight on the rail under the wheel, expressed as per cent. In the above example the coefficient of adhesion is 25 per cent., because a comparison between the adhesion and the weight on the rail shows that the former is 25 per cent. of the latter. The importance of knowing the value of the term is that it enables one to calculate the adhesion when the weight on the rail under the wheel is given. The coefficient of adhesion depends entirely upon the condition of the rail, and if this does not change the coefficient of adhesion will remain the same. When the rails are dry and clean the coefficient of adhesion is about 25 per cent., but if the rails are wet the coefficient of adhesion may be as low as 15 per cent. An average value is 20 per cent. The coefficient of adhesion may be determined by using the following rule:

Rule.—*To find the coefficient of adhesion, multiply the adhesion by 100, and divide by the weight under the wheel.*

Example.—The weight on the rail under a wheel is 6,000 pounds, and the adhesion between the wheel and the rail is 1,200 pounds. What is the coefficient of adhesion?

Solution.—From the rule the coefficient of adhesion is equal to

$$\frac{1{,}200 \times 100}{6{,}000} = 20 \text{ per cent. Ans.}$$

26. Difference Between Adhesion and Coefficient of Adhesion.—The terms adhesion and coefficient of adhesion should not be confused. The term adhesion does not imply any comparison between the adhesion and the weight that is on the rail under the wheel, while the term coefficient of adhesion does.

27. Finding the Adhesion.—When the coefficient of adhesion and the weight of the wheel on the rail are given, it is an easy matter to calculate the adhesion or the total frictional force between the wheel and the rail. In Art. **25** the wheel was assumed to weigh 1,500 pounds and the coefficient of adhesion was 25 per cent., or .25. If it is required to find the total frictional force between the wheel and the rail, it is only necessary to multiply 1,500 by .25. The result is 375 pounds, or the total frictional resistance between the wheel and the rail. The following rule can be deduced from the foregoing:

Rule.—*To find the total frictional force between the wheels and the rail, multiply the weight under the wheels by the coefficient of adhesion.*

Example.—A car weighs 80,000 pounds. What is the adhesion when the coefficient of adhesion is 20 per cent.?

Solution.—The adhesion is equal to $80{,}000 \times .20 = 16{,}000$ lb. Ans.

28. Braking Force Limited by Adhesion.—The adhesion, or the total frictional force between the wheel and the rail, limits the braking force that can be applied to the wheel. The adhesion rarely exceeds 25 per cent. of the weight under the wheels and the friction of the brake shoes must not equal this amount, or the wheels will slide. In fact, the brake-shoe friction should be less to allow for a bad condition of the rails.

Under ordinary conditions there is little danger that the friction between the brake shoe and the wheel will exceed the friction between the wheel and the rail. Sixty per cent. of the empty weight of a freight car is used as the braking force; that is, for each 100 pounds of weight, 60 pounds is used as braking force. The coefficient of friction by which 60 pounds must be multiplied in order to give a frictional resistance of 25 pounds, is 41 per cent., or $60 \times .41 = 24.6$ per cent. This is a greater frictional resistance than the brake shoes can develop. The following example will show the difference that exists between the frictional resistance at the brake shoes and at the rail:

Example.—The brake-shoe pressure that is applied to the wheels of a car that weighs 80,000 pounds is 72,000 pounds. Find the difference

between the total frictional resistance at the rail and at the brake shoes, if the coefficient of adhesion is 25 per cent., and the coefficient of friction is 20 per cent.

SOLUTION.—The total frictional resistance at the rail is 80,000×.25, or 20,000 lb. The total frictional resistance at the brake shoes is 72,000×.20 or 14,400 lb. The difference is 20,000−14,400=5,600 lb. Therefore, there is a margin of 5,600 pounds of rail friction, which acts to prevent the wheels from sliding.

SLIDING WHEELS

29. Reason For a Wheel Sliding.—Before a wheel will stop revolving and begin to slide, the total frictional resistance between the brake shoe and the wheel must exceed the total frictional force, or the adhesion between the wheel and the rail.

The total frictional resistance between the brake shoe and the wheel is equal to the brake-shoe pressure multipled by the coefficient of friction, and the adhesion, or the total frictional force between the wheel and the rail, is equal to the weight on the rail under the wheel multiplied by the coefficient of adhesion.

When the brake is applied, the friction between the brake shoe and the wheel which tends to stop its rotation instantly sets up an equal and opposing friction between the wheel and the rail that resists any tendency to prevent the wheel from turning. That is, any tendency to stop the wheel from turning in one direction is resisted by the push of the rail against the wheel in the direction opposite to the movement of the train. However, the wheel will slide when the total frictional resistance between the brake shoe and the wheel becomes equal to or slightly exceeds the total frictional resistance between the wheel and the rail. In other words, the wheel will slide when the wheel pull exceeds the rail pull. Fig. 16 will serve to make the foregoing clear.

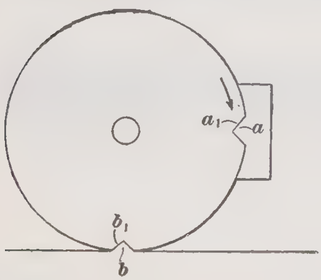


FIG. 16

It is assumed that the total frictional resistance between the brake shoe and the wheel is equal to that which is caused by the elevation a on the brake shoe when it engages the depression a_1 in the wheel. Likewise, the total frictional resistance between the wheel and the rail is assumed to be equal to that which is due to the elevation b on the rail when it engages the depression b_1 on the wheel.

The elevation a tends to stop the wheel from turning and this action of a forces the wheel against the elevation b, which resists the tendency produced by a. However, the frictional resistance exerted by a, as a is the greater, will exceed the frictional resistance that is exerted by b. The wheel, therefore, tears off the projection b and slides along the rail, because the wheel is prevented from turning by the projection a.

30. Turning and Sliding Wheels.—A wheel with the brake applied will always stop in a shorter distance when it is turning than when it is sliding. The reason is that rolling friction is static friction, and static friction is always greater than kinetic friction, or friction of motion. As long as the wheel turns, the friction between the wheel and the rail is rolling friction and the friction between the brake shoe and the wheel is kinetic friction. The instant the wheel begins to slide the rail friction becomes kinetic and the brake-shoe friction becomes static. The frictional resistance between the wheel and the rail immediately decreases and the result is that the wheel goes farther before it stops, when it is sliding than when it is turning.

BRAKE-RIGGING FORCES

BRAKING FORCE

31. Definition.—The term braking force refers to the force with which the brake shoes are forced against the wheels. Braking force and brake-shoe pressure mean the same. Braking force was formerly known as braking power, but this latter term is incorrect, as power refers to the rate of doing work,

and its unit of measurement is the horsepower, whereas the braking force or brake-shoe pressure is measured in pounds.

32. Nominal and Actual Braking Force.—Braking force may be either nominal or actual. The nominal braking force is a calculated force which cannot be obtained in practice, as the word *nominal* in this case means that no account is taken of the losses which occur in the transmission of brake-cylinder pressure to the brake shoes. These losses may be due to the effect of the release springs, the suspension of the brake hangers, the friction of the moving members of the brake rigging, and other causes. Tests have shown that the efficiency of a well-designed foundation brake rigging in transmitting brake-cylinder force to the brake shoes is about 85 per cent. In other words, 15 per cent. of the brake-cylinder force is lost in transmission.

The actual braking force takes into consideration all the losses that occur in the transmission of brake-cylinder pressure, and means the actual brake-shoe pressure obtained when any given brake application is made.

The nominal braking force is based on the braking force obtained from either a full-service or an emergency application. The actual braking force is that obtained from any service application or an emergency application. Unless otherwise stated, the term braking force refers to the nominal service-braking force.

The following will serve to show the difference between the nominal and the actual braking force: If, in a full-service application, there is a calculated pressure of 2,500 pounds against one brake shoe, and if there are eight shoes, the nominal braking force is $2{,}500 \times 8 = 20{,}000$ pounds. If a test showed that the pressure actually developed was 17,500 pounds, this would be the actual braking force.

33. Pressure on Which Braking Force is Based. The service-braking force for a freight car is based on a brake-cylinder pressure of 50 pounds and the service-braking force for the PM, LN, and UC equipments is based on a brake-cylinder pressure of 60 pounds. The service-braking force for

the PC equipment is based on a brake-cylinder pressure of 86 pounds. An emergency application with any of the equipments just mentioned will develop a higher brake-cylinder pressure. For example, an emergency application with freight equipment gives a brake-cylinder pressure of 60 pounds.

The emergency-braking force is then based on the brake-cylinder pressure obtained in emergency and is as follows: 60 pounds for freight equipment; 85 pounds for the PM equipment, which pressure gradually reduces to 60 pounds; 100 pounds for the LN equipment; and 100 pounds for the UC equipment. With the PC equipment, which uses two brake cylinders, the same pressure is obtained in each as in service, or 86 pounds. With later types of PC equipment, the emergency-brake cylinder is 2 inches less in diameter than the service-brake cylinder, and this reduces the brake-cylinder force obtained in emergency.

The higher brake-cylinder pressure in emergency with the LN and UC equipments is obtained by the use of an extra reservoir, which discharges to the auxiliary reservoir. The effect of this is to give a higher brake-cylinder pressure. The PC equipment uses an extra reservoir, as well as another brake cylinder, to obtain a high pressure.

BRAKING RATIO

34. Definition.—The meaning of the term *braking ratio* will be explained by the following example: If it is assumed that a car weighs 100,000 pounds when empty and that the braking force is 60,000, a comparison between the braking force and the weight of the car is made by dividing the braking force by the weight. Thus, $\frac{60000}{100000} = \frac{6}{10}$, or 60 per cent. Therefore, a comparison between the braking force and the weight shows that the former is 60 per cent. of the latter.

The term braking ratio is applied to the comparison between the braking force and the weight of a car when empty, expressed in per cent. The reason for the use of the term braking ratio is that it enables a person to calculate the braking force when the empty weight of the car is known. In the

example given the braking ratio is 60 per cent. or .60, because a comparison between the braking force and the weight shows that the braking force is 60 per cent. of the weight. A braking ratio of 60 per cent. means that a braking force of 60 pounds is used for each 100 pounds of car weight. The braking force of freight cars is always less than the empty weight of the car, but with modern passenger cars, the braking force always exceeds the empty weight of the car.

The braking ratio is based on the weight of the car when it is empty, because if it were based on the weight of the car when it was loaded, the braking force would be so great when the car was unloaded that there would be danger of sliding the wheels.

The term formerly used for braking ratio was *per cent. braking power,* but, as already explained, the term power in this instance is incorrect. The term per cent. of braking force is also sometimes used with a meaning the same as braking ratio. However, as it is desired to compare the braking force with the light weight of the car, and as the word *ratio* means a comparison, the term braking ratio is the correct one to use.

35. Rule for Finding Braking Ratio.—The braking ratio can be found from the following rule:

Rule.—*To find the braking ratio, multiply the braking force by 100 and divide by the weight of the car when empty.*

EXAMPLE.—A car when empty weighs 50,000 pounds, and the braking force is 30,000 pounds. What is the braking ratio?

SOLUTION.—From the rule, the braking ratio equals

$$\frac{30{,}000 \times 100}{50{,}000} = 60 \text{ per cent. Ans.}$$

36. Finding Braking Force from Braking Ratio. As the braking ratio indicates the per cent. of the empty weight of a car which is used for the braking force, the braking force can be found from the following rule:

Rule.—*To find the braking force, multiply the empty weight of the car by the braking ratio.*

EXAMPLE.—A car weighs 120,000 pounds, and the braking ratio is 90 per cent. What is the braking force?

SOLUTION.—From the rule, the braking force equals 120,000×.90 (90%) or 108,000 lb. Ans.

37. Braking Ratio Affected by Loading.—As the braking force remains the same whether the car is empty or loaded, the braking ratio will be affected by loading the car. If a box car weighs 50,000 pounds when empty, and it is capable of carrying a load of 100,000 pounds, if the braking force is 30,000 pounds, the braking ratio when the car is empty is $\frac{30{,}000 \times 100}{50{,}000}$, or 60 per cent. The total weight of the car when loaded is 150,000 pounds, but the braking force remains the same, or 30,000 pounds. The braking ratio is now equal to $\frac{30{,}000 \times 100}{150{,}000} = 20$ per cent. Therefore, the braking ratio decreases when the car is loaded.

The foregoing applies to the single-capacity brake. With the empty and loaded brake, the braking ratio is 60 per cent. when the car is empty and 40 per cent. when the car is loaded. The difference between the weight of a passenger car when it is loaded and empty, is small, and the braking ratio is not affected to any great extent by the load.

38. Nominal and Actual Braking Ratio.—As the braking force is either nominal or actual, the braking ratio must also be either nominal or actual. The nominal braking ratio is the relation between the nominal braking force calculated on a full-service or an emergency application, and the weight of the car when it is empty. The actual braking ratio refers to the relation between the braking force that results from any brake application and the weight of the car, whether it is loaded or empty.

Unless otherwise stated, the braking ratio means the nominal braking ratio with the braking force based on a full-service application.

39. Service-Braking Ratios.—In Table I is given the service-braking ratios that are used with the various car-brake equipments. It is often required to know the brake-cylinder pressure on which the braking force is based. Therefore, the brake-cylinder pressures from Art. **33** have been repeated. This table shows that the braking ratio for freight cars is lower than for passenger cars. The reason is that the speed of freight cars is slower, and the slower the speed, other things being equal, the more effective the brake shoes are in retarding the speed of the wheels.

TABLE I

SERVICE-BRAKING RATIOS FOR FREIGHT AND PASSENGER CARS

Equipment	Braking Ratio Per Cent.	Brake-Cylinder Pressure On Which Braking Force Is Based Pounds
Freight..........	60	50
PM.............	90	60
LN..............	90	60
PC..............	90	86
UC..............	90	60

The table also shows the braking ratio is higher on passenger cars than on freight cars, although the brake-cylinder pressure is the same, or 60 pounds. The reason is that a larger brake cylinder is used on a passenger car, and the braking force is, therefore, greater.

40. Table II gives the braking ratio for locomotives when the ET and A-1 brake equipments are used, and also the brake-cylinder pressure on which the braking force is based.

TABLE II

SERVICE-BRAKING RATIOS FOR LOCOMOTIVES AND TENDERS

Equipment	Braking Ratio Per Cent.	Brake-Cylinder Pressure on Which Braking Force Is Based Pounds
ET (Passenger)	60	50
ET (Freight)	50	50
ET (Tender) (Passenger)	80	50
ET (Tender) (Freight)	70	50
ET (Truck and trailer)	45	50
A-1 (Passenger)	75	50
A-1 (Freight)	65	50
A-1 (Tender) (Passenger)	85	50
A-1 (Tender) (Freight)	80	50
A-1 (Truck and trailer)	60	50

41. Emergency-Braking Ratios.—In Table III are given the emergency-braking ratios that are used with the different car equipments, as well as the brake-cylinder pressure on which the braking force is based.

TABLE III

EMERGENCY-BRAKING RATIOS FOR FREIGHT AND PASSENGER CARS

Equipment	Braking Ratio Per Cent.	Brake-Cylinder Pressure On Which Braking Force Is Based. Pounds
Freight	72	60
PM	90	85
LN	150	100
PC	150	86
UC	150	100

With freight equipment, the service-braking ratio is 60 per cent. with 50 pounds pressure. Therefore, the emergency-braking ratio is 72 per cent. with 60 pounds pressure. However, 70 per cent. is usually taken as the emergency-braking ratio. The braking ratio of the PM equipment is 125 per cent. with a brake-cylinder pressure of 85 pounds. However, as this pressure blows down to 60 pounds, the braking ratio is given as 90 per cent. The calculated emergency-braking ratio with the LN equipment and 104 pounds brake-cylinder pressure is 156 per cent. However, the single-brake-shoe rigging is generally used with this equipment, and as this causes a reduction in brake-cylinder pressure on account of false piston travel, the braking ratio will be less than the amount given. Therefore, the braking ratio is given as 150 per cent. with a brake-cylinder pressure of 100 pounds. With the PC equipment, it is assumed that the emergency brake cylinder is smaller than the service cylinder, and the emergency-braking ratio is accordingly reduced from 180 to 150 per cent.

42. Service- and Emergency-Braking Ratios.—It will be noted that the emergency-braking ratios are much higher than the service-braking ratios. The reason is that the smoothness of the stop is not taken into account in emergency, the only consideration at this time being the development of sufficient braking force to stop as quickly as possible so long as this force does not exceed the adhesion between the wheels and the rail.

The reason the higher emergency ratios given do not cause the wheels to slide is that the frictional force of the brake shoes at high speed is less than the adhesion between the wheel and the rail. This is explained in Art. **22.** Tests have shown that the sliding of wheels is influenced more by the condition of the rails than by a high brake-shoe pressure. At low speed the coefficient of friction is high and an emergency application with a high braking ratio will then probably cause the wheels to slide.

43. Difference Between Rail Friction and Brake-Shoe Friction.—The following example shows the differ-

ence between the rail friction and the brake-shoe friction when a high-emergency braking ratio is used:

Example.—A car weighs 120,000 pounds and has a braking ratio of 150 per cent. What is the difference between the frictional resistance at the rail and the wheel when the average coefficient of friction is 15 per cent., and the coefficient of adhesion 25 per cent.?

Solution.—The braking force is equal to 120,000×150 per cent., or 1.5=180,000 lb. The friction developed by the brake shoes is equal to the braking force multiplied by the coefficient of friction, or 180,000×.15 =27,000 lb.

The friction between the wheel and the rail is equal to the weight of the car multiplied by the coefficient of adhesion, the friction is, therefore, equal to 120,000×.25=30,000 lb. The brake-shoe friction is equal to 27,000 lb. The difference between 30,000 lb., the rail friction, and 27,000 lb., the wheel friction, is 3,000 lb., which is the excess to keep the wheel turning. Ans.

PISTON TRAVEL

EFFECT AND ADJUSTMENT

44. Definition.—By the term *piston travel* is meant the distance the brake-cylinder piston travels from release position when a full-service application is made.

45. Necessity of Uniform Piston Travel.—In order to obtain the same braking force or brake-shoe pressure, it is essential that the piston travel shall be the same on all cars.

The brake-shoe pressure is the result of the brake-cylinder pressure and the pressure developed in the brake-cylinder depends on the brake-cylinder volume into which the air from the auxiliary reservoir expands when an application of the brake is made. The brake-cylinder volume depends on the piston travel and it increases with the travel. Therefore, when the piston travel is long, the brake-cylinder pressure will be less than when the travel is short, because the amount of air that enters the brake cylinder is dependent on the brake-pipe reduction. Therefore, the same amount of air passes to the brake

cylinder whether the piston travel is long or short. The braking force will be greater on a car with a short travel, and this car, when the brakes are applied, will stop sooner than a car on which the travel is longer. Unequal piston travel is then undesirable, as it causes shocks when trains are stopped on account of the unequal braking forces that are developed on the different cars.

Unequal braking forces on the cars are also liable to cause the wheels to slide when the brakes are applied. When the brakes are applied the cars with the high-braking force will stop quicker than the cars with the low braking force. The cars with the low braking force then transmit a push or a pull to the cars with the high braking force. For an instant the cars with the high braking force will be moving faster than the speed at which their wheels are revolving, and at such a time the wheels are liable to slide.

46. Standing and Running Piston Travel.—The standing piston travel is the piston travel when the car is not in motion and the running piston travel is the travel when the car is moving. The running piston travel is always more than the standing piston travel. The reason is that the lost motion that exists in the truck-center bearings is more readily taken up when the car is moving than when it is standing. The running travel is generally from 1 to 3 inches greater than the standing travel.

The standard piston travel for all forms of car brakes is 8 inches, and this means the running travel, because if the standing travel were meant, the running travel would be more than 8 inches. The practice is then to adjust the standing travel so that the proper running travel will be obtained when the car is moving. This requires that the standing travel be about 6½ inches, and a standing travel of this amount will give a running travel of about 8 inches.

47. False Piston Travel.—By the term *false piston travel* is generally meant the difference between the running and the standing travel. But, strictly speaking, it means the difference in piston travel caused by the springing of the brake

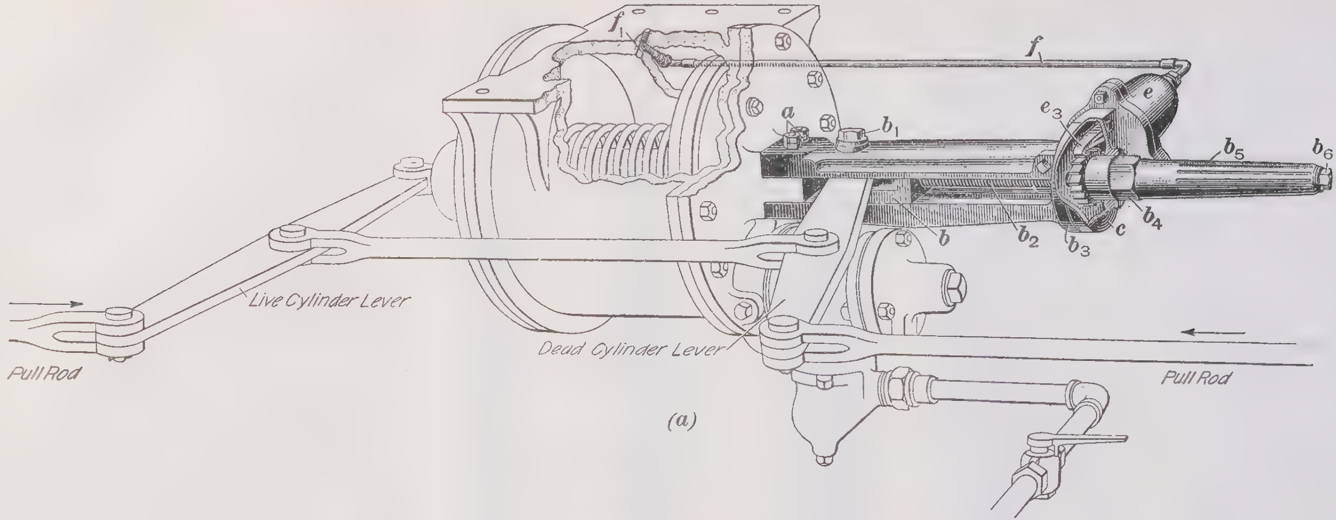
beams, levers, and other parts of the foundation brake rigging and the pulling down of the truck frames, and, therefore, of the brake shoes. False piston travel is, then, due to poor foundation brake-rigging design, and it increases with the brake-cylinder pressure.

THE AMERICAN AUTOMATIC SLACK ADJUSTER

48. Purpose.—The purpose of the American automatic slack adjuster is to maintain automatically a uniform running piston travel of 8 inches. A piston travel in excess of this amount due to brake-shoe wear or other causes, is shortened 1/30 inch each time the brake releases. Slack adjusters are applied only to passenger cars.

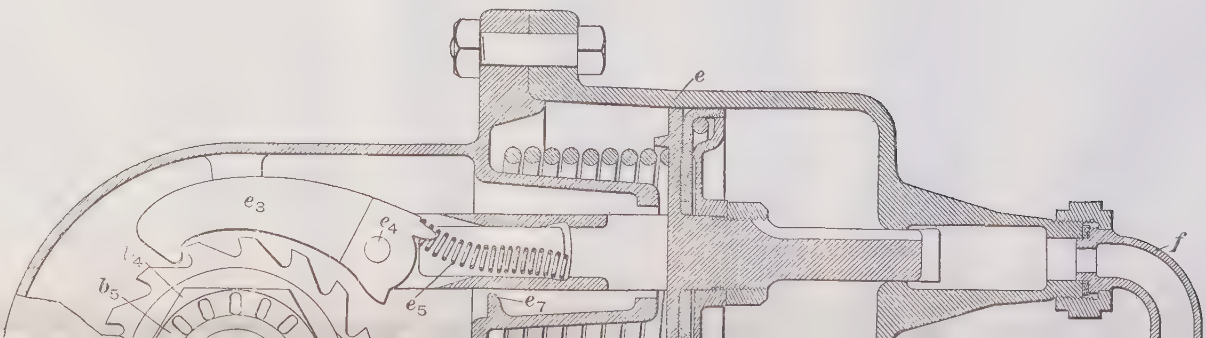
49. Construction.—The construction of the automatic slack adjuster will be explained by referring to Fig. 17. View (*a*) shows that the slack adjuster is attached to a projection on the pressure head of the brake cylinder by two bolts and nuts *a*. The crosshead *b*, which operates between the two guides shown, is connected to the end of the dead-cylinder lever by a bolt. The bolt may be removed and replaced by taking off the cap nut b_1. The threaded adjuster rod b_2 is attached to the cross-head, and this rod extends back through an opening in the part b_3 which is cast with the guides, and also through a hole in the casing *c*. This casing is bolted to the part b_3, and it is shown partly broken so that the interior may be seen. A ratchet nut b_4 is screwed on to the outer end of the adjuster rod and the inner face of this nut bears against the outer face of the part b_3. The ratchet nut turns freely where it passes through the casing *c*. The ratchet nut differs in shape from the usual form of nut inasmuch as it has a hollow extension b_5 which protects the thread on the adjuster rod, and it also has a series of teeth cut around the outside of its inner end as shown. It is for this latter reason, that the nut is called a *ratchet nut*. The part of the nut with its teeth is enclosed by the casing *c*.

The adjuster cylinder *e* which is shown in section in views (*b*) and (*c*), is bolted to the casing *c*. The cylinder, view (*b*), contains a piston e_1 with a packing leather, spring, and fol-

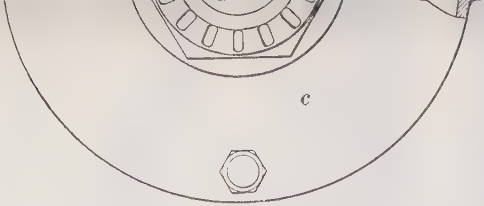


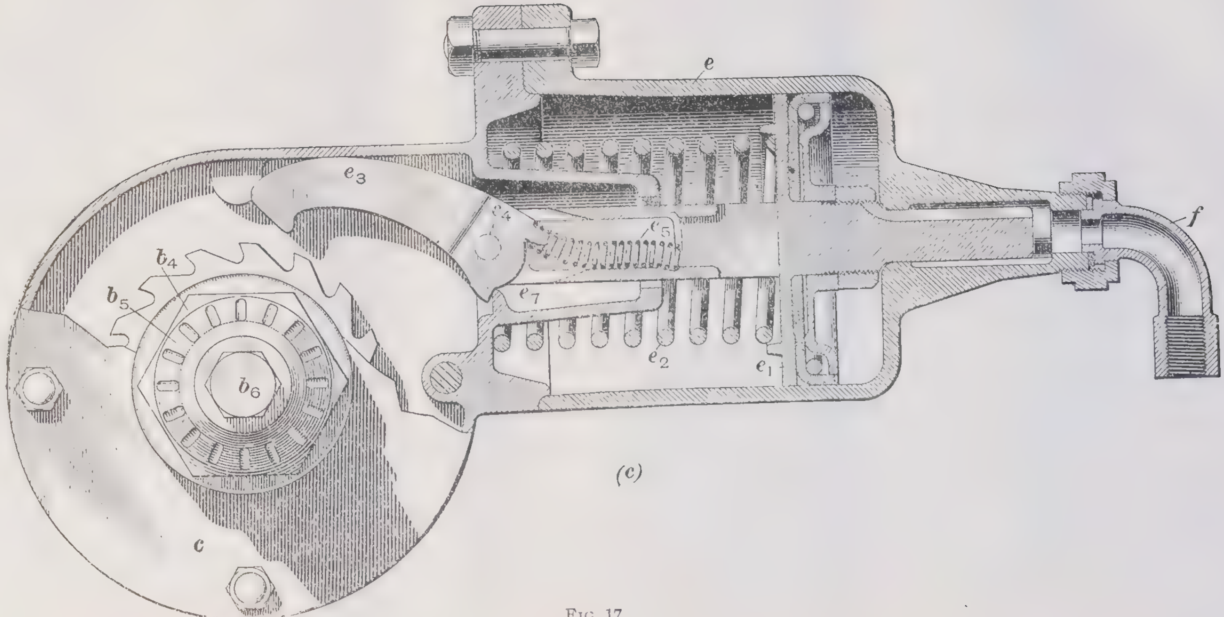
f_1
f
e
e_3
a
b_1
b_5
b_6
b
b_2
b_3
c
b_4
Live Cylinder Lever
Dead Cylinder Lever
Pull Rod
Pull Rod

(a)



e
e_3
e_4
b_4
b_5
e_5
e_7
f


(b)



(c)

FIG. 17

lower, a spring e_2, a pawl e_3 which is connected by a pin e_4 to the piston stem, and a pawl spring e_5. The pawl e_3 extends into the casing c above the ratchet nut. A pipe f, view (a), connects the adjuster cylinder to a hole f_1 which is tapped into the brake cylinder. The air in the brake cylinder can enter port f_1 when the brake-cylinder piston moves out about 8 inches.

50. Operation.—The following preliminary explanation will serve to make the operation of the slack adjuster more readily understood. If we assume that the ratchet nut is turned to the right by applying a wrench to the flattened surfaces of the nut, the ratchet nut cannot be screwed forwards on the rod because the end of the nut bears against the inner face of the part b_3 of the adjuster. Therefore, when the nut is turned the rod will be drawn outwards through the hollow ratchet nut. The crosshead and the end of the dead cylinder lever will move in the same direction as the rod. The pull rods will be moved in the direction of the arrows, and the brake shoes will thereby be brought nearer the wheels.

The manner in which the ratchet nut is turned by the air pressure is as follows: When the piston in the brake cylinder moves far enough to allow the packing leather to pass the port f_1, the air from the brake cylinder passes through pipe f to the adjuster cylinder e. The adjuster piston e is forced forwards, view (b), and the pawl e_3 which is forced downwards by the spring e_5, engages one of the teeth of the ratchet nut. The pawl moves over two teeth of the ratchet nut each time the adjuster operates. When the brake is released and the brake-cylinder piston moves back past port f_1 the air in the adjuster cylinder passes to the atmosphere through the non-pressure head of the brake cylinder. The spring e_2 in the adjuster cylinder forces the piston e_1 back and the pawl turns the ratchet nut about one-eighth of a turn. This shortens the piston travel one-thirtieth of an inch. As the take-up movement is almost completed the pawl e_3 engages the projection e_7 view (c) and the pawl is thrown out of contact with the ratchet nut. As one application of the brakes shortens the piston travel one-thirtieth of an inch, it will require thirty brake applications

to shorten the travel 1 inch. This requires that the ratchet nut be turned about four times.

51. Letting Out the Slack.—The adjuster is only automatic when the slack is being taken up. The slack must always be let out by hand. This is done by turning the ratchet nut to the left with a wrench. When it is desired to let out the slack the ratchet nut should be always moved slightly to the right before it is turned to the left. This precaution is necessary to free the pawl in the event of its being stuck in a tooth of the ratchet. The teeth or the pawl would be damaged were an attempt made to turn the ratchet nut to the left when the pawl is engaged with the nut.

52. Purpose of Stop Screw.—The purpose of the stop screw b_6 is to enable one to let out the slack after it has been all taken up. When the slack is all taken up, the end of the threaded rod is up against the stop screw, and the pawl remains engaged with the ratchet nut, because the nut cannot now move the rod any farther. The pawl can be freed by removing the stop screw, as this permits a sufficient take-up movement to free the pawl. The slack can then be let out.

53. Replacing Brake Shoes.—When new brake shoes are to be applied the slack should be let out, as already explained. If the slack is all taken up one should proceed as explained in Art. **52.** Sufficient slack should be let out to permit of at least $8\frac{1}{4}$ inches piston travel after the new shoes are applied. After the shoes have been applied, it is necessary to take up the slack so that the standing piston travel is $6\frac{1}{2}$ inches, because with this standing travel the running travel will be about 8 inches. To do this, the brakes should be set in full, and the piston travel measured. If the piston travel is found to be 9 inches, the brake should be released and the ratchet nut turned to the right until the slack-adjuster crosshead moves $2\frac{1}{2}$ inches toward the adjuster cylinder. The standing travel will then be $6\frac{1}{2}$ inches.

54. Adjuster Takes Up too Much Slack.—The primary purpose of the slack adjuster is to prevent the running

piston travel from exceeding a certain amount, due to the wear of the brake shoes or to the lost motion in the brake-rigging connections. However, any other condition which may bring about a long piston travel, will also cause the adjuster to operate. As will be explained later, a single-shoe type of foundation brake rigging causes an excessive piston travel when the brakes are applied while the car is in motion, especially if the braking ratio is high. The car may start out with the correct standing travel, but as the running travel is so much more, the adjuster will operate at each brake application. As a result, when the car reaches a terminal the standing piston travel may be so short that the brake shoes will not clear the wheels. Therefore, when the slack adjuster takes up too much slack, it does not imply any disorder in the adjuster. Such a condition points out the necessity of a proper design of brake rigging.

55. To Take Up Slack on Freight Equipment. The slack in freight-brake equipments is taken up by hand because these equipments are not supplied with slack adjusters. The dead truck levers are secured in the guides by pins. When necessary the slack is taken up by removing the pins and moving the levers to holes that are nearer the brake cylinders. The slack is taken out by moving the ends of the levers in the opposite direction in the guides. The parts of the brake beams through which the truck levers pass sometimes have holes for the purpose of adjusting the slack.

LEVERAGE RATIO

56. The *leverage ratio* of a single lever is found by dividing the force that is delivered by the force that is applied. For example, if the applied force is 10 pounds and the delivered force is 50 pounds, the leverage ratio is said to be 5 to 1. It then follows from the principles of levers that the length of the lever between the applied force and the fulcrum is five times as long as the length of the lever between the delivered

force and the fulcrum. The point at which the force is applied will then move five times as far as the end at which the force is delivered.

The foregoing also applies to a system of levers such as the foundation brake rigging. If it is assumed that a brake-cylinder force of 4,000 pounds delivers when it is transmitted through the brake levers, a brake-shoe pressure of 32,000 pounds, the result obtained when 32,000 is divided by 4,000 is 8, and the leverage ratio is 8 to 1. A leverage ratio of 8 to 1 as applied to the brake then means that the brake-cylinder force is multiplied eight times by the levers of the rigging before it is transmitted to the brake shoes. In this case the brake-cylinder piston will move eight times as far as the brake shoes.

57. Reason for not Using a High-Leverage Ratio. It is not always apparent why the brake-cylinder force cannot be increased to any extent desired by the use of levers. The reason will be understood when it is remembered that an increase of force by the use of a lever always implies that the end of the lever at which the force is applied must move farther than the end at which the force is delivered. In other words, a gain in force is accomplished only at the expense of distance. Therefore, if the brake-cylinder force is greatly increased by the brake rigging the brake cylinder would have to be made longer so as to permit the end of the lever where the force is applied, to move the required amount. A larger brake cylinder would require a larger auxiliary reservoir and also a larger main reservoir. In order to keep the size of the brake equipment within reasonable limits, it is necessary to limit the leverage ratio which is used. The usual leverage ratio is 8 to 1 or 9 to 1. Two brake cylinders are used if a greater brake-shoe pressure is desired than can be developed from these ratios.

58. In Figs. 18 and 19 are shown the effect of using a high-leverage ratio. These figures assume that the brake rigging consists of a single lever and a brake shoe. The piston travel in Fig. 18 is 8 inches and the leverage ratio is 8 to 1 because the arm *ab* is eight times as long as the arm *bc*. From

the principles of levers the brake-cylinder piston must move the end *a* 8 inches in order to move the point *c* or the brake shoe 1 inch. If the piston travel is 8 inches the brake shoe will stand 1 inch from the wheel, or the brake-shoe clearance will be 1 inch when the brake is released.

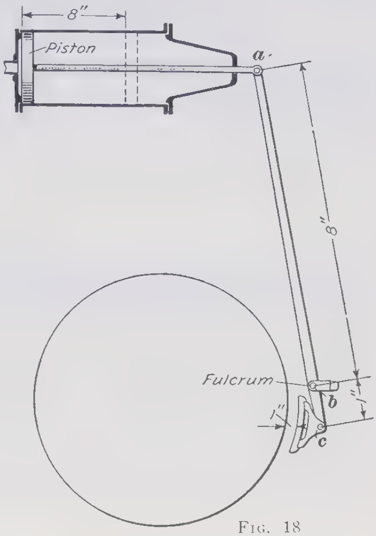


FIG. 18

In Fig. 19 the leverage ratio is 16 to 1 and the piston travel is 8 inches. The end *a* of the lever must now move 16 inches in order to move the brake shoe 1 inch. As the movement of the end *a* is restricted to 8 inches, the brake shoe will move ½ inch when the brake is applied. The brake-shoe clearance is then reduced to ½ inch when the leverage ratio is doubled. The brake-shoe clearance may be increased by simply hanging the brake shoe farther from the wheel. If the brake shoe is hung ½ inch farther from the wheel, making the total shoe clearance 1 inch, the piston would have to move 16 inches before the brake shoe would strike the wheel, and the length of the brake cylinder is limited to 12 inches.

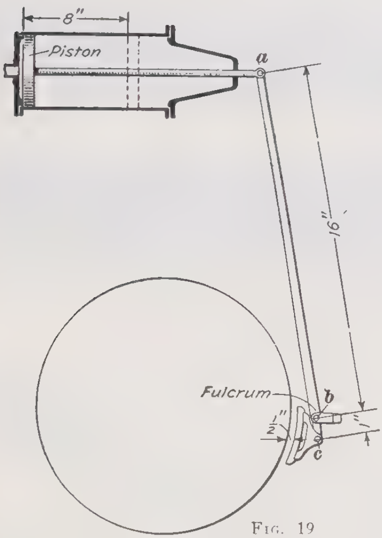


FIG. 19

59. When the leverage ratio is high, the piston travel will increase more on account of brake-shoe wear or other con-

ditions which may cause an increase in travel, than when the leverage ratio is low. Thus, when the leverage ratio is 16 to 1 the piston travel will increase twice as much as when the ratio is 8 to 1. If the ratio is 16 to 1 and the brake-shoe wear is $\frac{1}{8}$ inch, the brake-cylinder piston will move sixteen times $\frac{1}{8}$ inch or 2 inches farther than before, whereas when the ratio is 8 to 1 the piston will move eight times $\frac{1}{8}$ inch, or 1 inch farther.

Therefore, a high-leverage ratio cannot be used when the piston travel is limited to a fixed amount, because the result would be a reduced shoe clearance, and excessive piston travel from brake-shoe wear, springing of the brake rigging, journals moving in their brasses or slack in the center bearings.

60. Brake-Shoe Clearance.—The brake-shoe clearance can easily be found when the leverage ratio is known. If the leverage ratio is 8 to 1, the brake-cylinder piston must move 8 inches in order to move the brake-shoe 1 inch. Therefore, when the piston travel is 6 inches, the brake shoes move $6/8$ or $\frac{3}{4}$ inch, which will be the shoe clearance. The shoe clearance can then be found from the following rule:

Rule.—*To find the shoe clearance, divide the piston travel by the leverage ratio.*

61. Finding Braking Force From Leverage Ratio. The braking force can be found when the leverage ratio and the brake-cylinder force is known. For example, a pressure of 50 pounds in a brake cylinder that is 10 inches in diameter, will give a force of 3,950 pounds on the brake-cylinder piston. If the leverage ratio multiplies this force eight times, the nominal or calculated service-braking force would be equal to $3,950 \times 8 = 31,600$ pounds,

FOUNDATION BRAKE RIGGING

(PART 2)

ACTION AND CALCULATION OF BRAKE-RIGGING FORCES—(Continued)

BRAKE RIGGING

1. Purpose and Requirements.—The purpose of the foundation brake rigging is to increase and transmit to the wheels equally the force exerted by the compressed air in the brake cylinder. Therefore the foundation brake rigging forms the connecting link between the brake cylinder and the wheels, and converts the air pressure in the cylinder into mechanical force on the wheels. It consists of a system of levers, rods, pins, hangers, brake beams, and brake shoes.

The first and essential requirement of the foundation brake rigging is that it be designed with due regard to strength, rigidity, and arrangement so as to insure a piston travel as nearly constant as possible under all variations in brake-cylinder pressure. The brake rigging should be designed also so that the pressure applied to the wheels will not force the journals from under their bearings and cause journal troubles.

TYPES OF BRAKE RIGGING

2. Names of Types.—Foundation brake rigging may be classed as of two general types, according to the number of brake shoes that are used per wheel. The *single-shoe-per-wheel type* uses one brake shoe for each wheel, and is universally used on freight cars and the older passenger cars. The *two-shoe-*

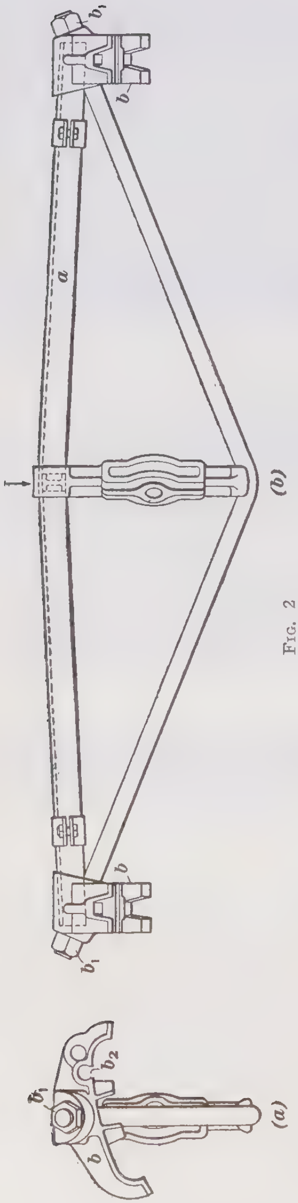
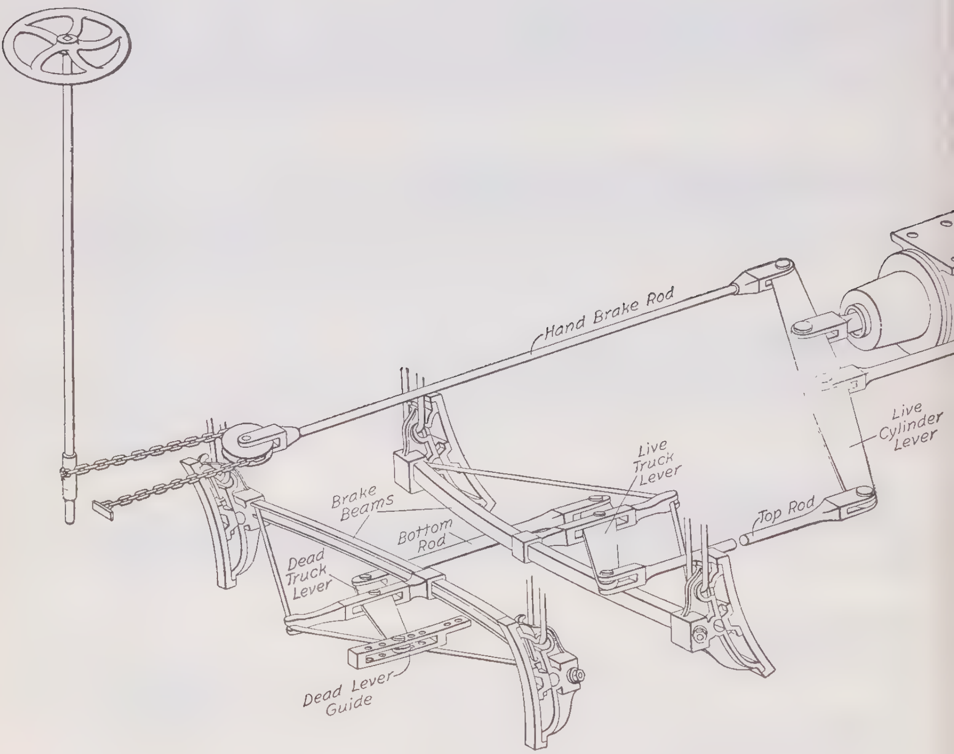


Fig. 2

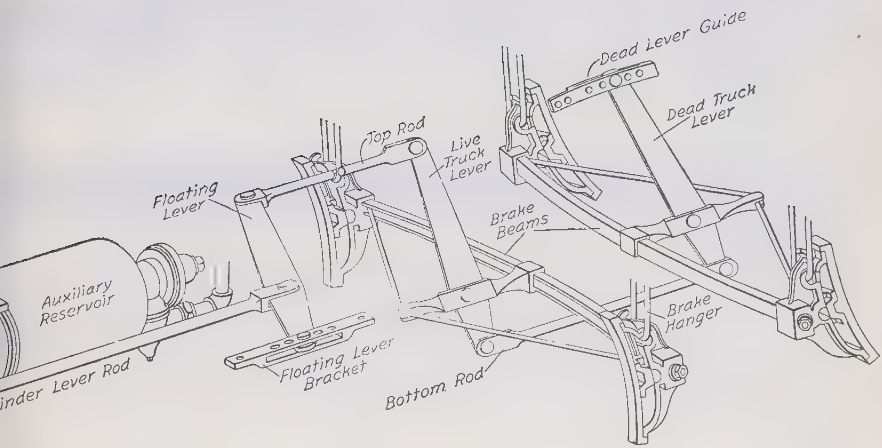
per-wheel type uses two brake shoes for each wheel and is in universal use on modern passenger cars. This type of brake rigging is commonly known as the *clasp brake.*

SINGLE-SHOE-PER-WHEEL TYPE OF BRAKE RIGGING

3. Description.—In Fig. 1 is shown a single-shoe-per-wheel type of brake rigging for a freight car, with the principal parts named. The live cylinder lever is pinned to the brake-cylinder piston. One end of this lever is pinned to the hand-brake rod and the other end is pinned to the top rod. The cylinder-lever rod connects the live cylinder lever to the floating lever. One end of the floating lever is connected by a pin to the floating-lever bracket and the other end of the lever is pinned to the top rod, which is connected to the upper end of the live truck lever and the lower end of the lever is pinned to the bottom rod. The brake beam is connected to the live truck lever between its ends. The bottom rod is connected by means of a pin to the lower end of the dead truck lever and the upper end of this lever is pinned to the dead lever guide. The brake beam is pinned to the dead truck lever between the ends. The arrangement of the brake rigging is the same on the other truck. The brake beams are suspended by brake hangers to a


Hand Brake Rod
Live
Cylinder
Lever
Live
Truck
Lever
Brake
Beams
Bottom
Rod
Top Rod
Dead
Truck
Lever
Dead Lever
Guide

FIG


Dead Lever Guide
Dead Truck
Lever
Top Rod
Live
Truck
Lever
Floating
Lever
Brake
Beams
Auxiliary
Reservoir
Brake
Hanger
inder Lever Rod
Floating Lever
Bracket
Bottom Rod

part of the car truck. The floating-lever bracket is connected to the car sill and the dead lever guides are connected to the truck bolster.

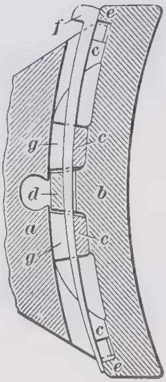
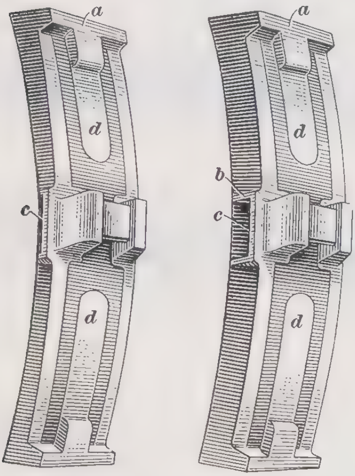


Fig. 3

4. Details of the Parts.—Two views of a brake beam are shown in Fig. 2. The brake heads b are secured to the brake beam by nuts b_1. The brake hangers rest in a semicircular recess b_2, view (a) in the brake head. The hangers are held in place by the brake shoes when they are attached to the brake head. The brake beam shown in Fig. 2 is only one of the many types in use.

A vertical section of a brake shoe and a part of the brake head is shown in Fig. 3, and illustrates how the brake shoe is secured to the head. The brake head a has four contact surfaces c, and the brake shoe is held against these surfaces by the brake-shoe key f. This key passes through the eyes g in the brake head and the eye d in the shoe. The brake-shoe key also makes a contact with the shoulders e of the brake shoe. The brake hanger rests in the semicircular recess shown in the brake head.



(b) (a)

Fig. 4

In Fig. 4 (a) and (b) are shown two views of a brake shoe. The brake shoe has a mark at b similar to a section cast on the side of the shoe. When the shoe is worn down where only the portion c of the mark remains, as in view (b), the brake shoe must be discarded. The portions marked d are inserts of mild steel which serve to retain the pieces in

position in case the shoe is fractured. The brake shoes used on passenger cars are usually flanged so that they engage not only the tread but also the flange of the wheel.

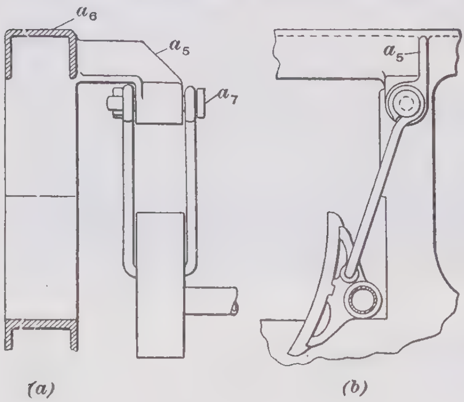


Fig. 5

Fig. 5 (*a*) and (*b*), shows how the brake beams are suspended to the truck when the side frame of the truck is in one piece. A brake-hanger carrier a_5 is cast on the side frame a_6 of the truck and the brake hanger is connected to it by the brake hanger pin a_7. In Fig. 6 (*a*) and (*b*) is shown the method of suspending the brake beams with an arch-bar truck. The brake-hanger carrier is cast with the column casting or bolster guide, as shown, and the brake hanger is pinned to it.

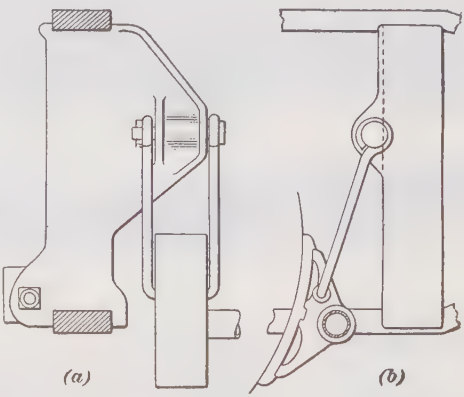


Fig. 6

With either of these arrangements the loading or unloading of the car does not affect the position of the hangers and the brake beams, as the hanger carriers are not affected by the movement of the truck bolster.

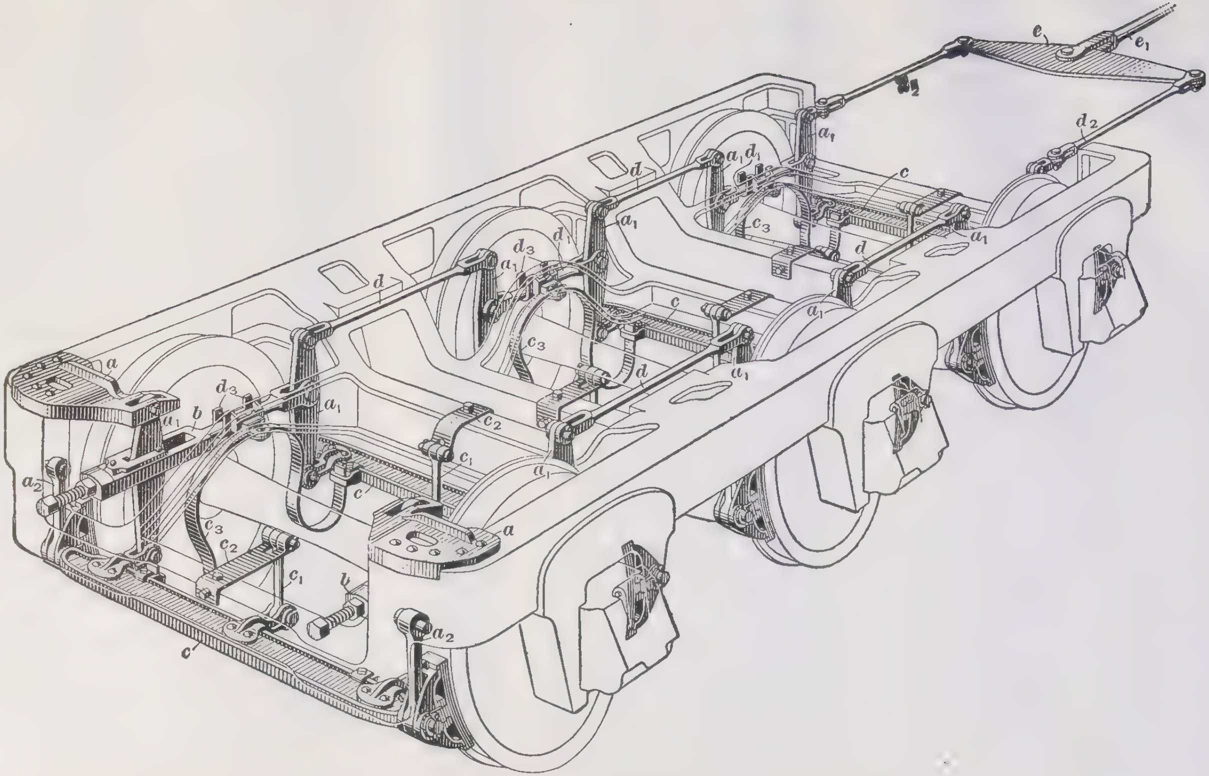


Fig. 7

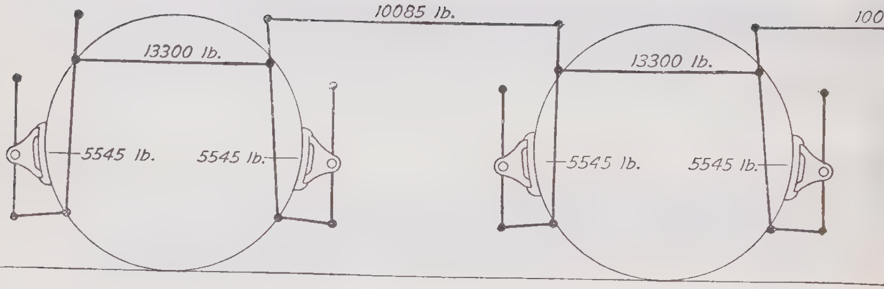
THE TWO-SHOE-PER-WHEEL TYPE OF BRAKE RIGGING (CLASP BRAKE)

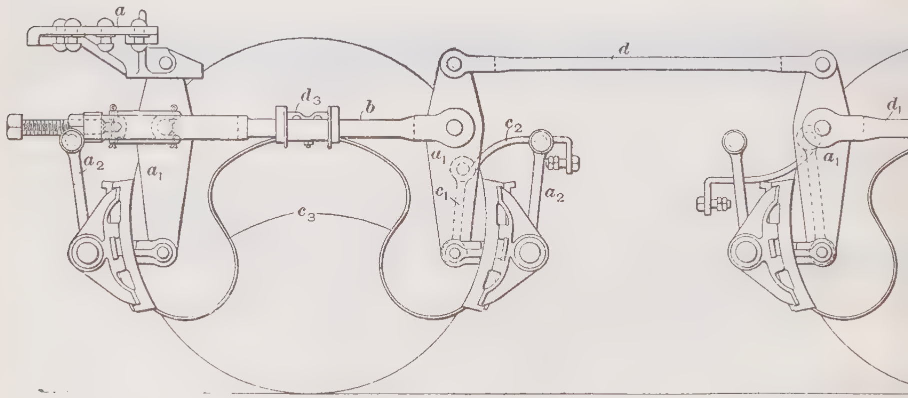
5. Description.—In Fig. 7 is shown the clasp-brake type of brake rigging as applied to a six-wheel truck. Fig. 8, view (*a*), shows the brake rigging as viewed from the side. View (*b*) is an outline of the gear and shows the stresses on the different points. This view will be referred to when the calculation of brake-rigging forces are taken up later on.

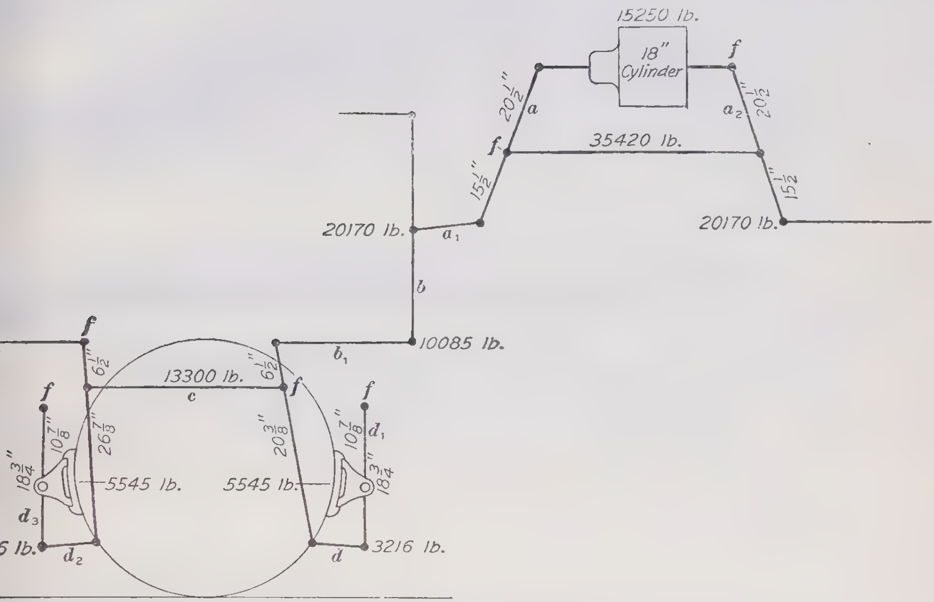
The names of the parts indicated in Figs. 7 and 8 are as follows: a, dead lever fulcrum; a_1, truck lever; a_2, brake hanger; b, slack-adjuster pull rod; c, brake beam; c_1, balance hanger; c_2, balance-hanger bracket; c_3, release spring; d, top truck rod; d_1, bottom truck rod; d_2, truck connecting-rod; e, horizontal equalizer; e_1, horizontal equalizer connecting-rod.

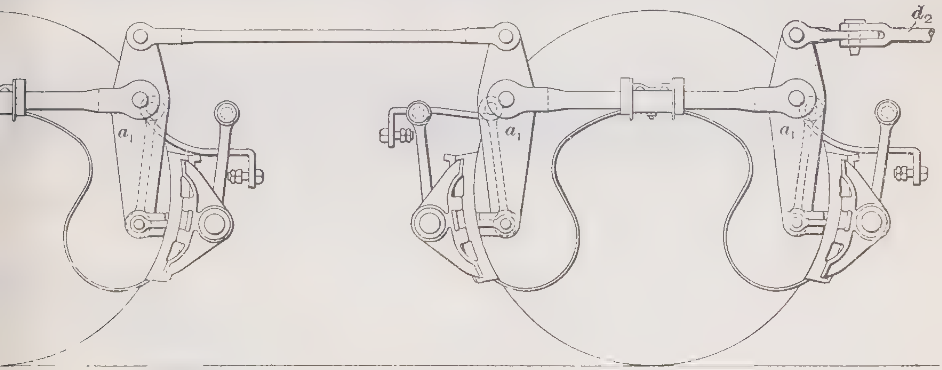
The lower ends of the truck levers, a_1, Fig. 7, are pinned to brackets riveted to the brake beams. The balance-hanger brackets c_2 are secured to the truck frame, and the balance hangers c_1 are pinned to the brackets and to brackets riveted to the brake beams. These hangers prevent the brake beams from tipping and thereby keep the brake beams in their proper position relative to the wheels. The release springs c_3 keep the brake shoes from dragging on the wheels when the brakes are released. These springs are clamped to the pull-rod guides d_3. The horizontal equalizer connecting-rod e_1 connects to the lower end of the live cylinder lever.

6. Slack Adjuster.—The slack adjuster, which is shown on the end of the slack-adjuster pull rod, Fig. 7, is an arrangement whereby the slack in the brake rigging may be taken up or let out as desired. The construction of the slack adjuster is shown in Fig. 9, views (*a*), (*b*), and (*c*). View (*a*) shows the slack adjuster as viewed from the top; view (*b*) shows the adjuster as viewed from the side; and view (*c*) shows the crosshead. The slack adjuster, view (*a*), consists of a copper plated threaded bolt a, a jamb nut a_1, a crosshead b which works in a slot in the slack-adjuster pull rod, two cotter keys b_1, one of which is shown in view (*b*), a cotter key b_2, and a cotter key b_3. The truck lever extends through the slot in the crosshead,


10085 lb.
100
13300 lb.
13300 lb.
5545 lb.
5545 lb.
5545 lb.
5545 lb.


a
d
d_3
b
c_2
d_1
a_2
a_1
a_1
c_1
a_2
a_1
c_3


15250 lb.
18" Cylinder
f
20½"
a
a2
35420 lb.
15½"
20170 lb.
a1
b
10085 lb.
b1
13300 lb.
c
6½"
26⅞"
20⅜"
10⅞"
d1
18¾"
5545 lb.
d3
d2
d
3216 lb.


d2
a1
a1
a1

view (*a*), and this lever is secured to the crosshead by the pin *c*. As shown in views (*b*) and (*c*), a slot is provided in the front end of the crosshead, and the pin *c* fits in this slot and is held in place by two cotter keys b_1 which extend down through the crosshead in front of the pin. The key b_2, view (*b*), extends through the crosshead and the threaded bolt *a*, and in combination with jamb nut a_1, serves to keep the bolt from turning. The key b_3 extends through the bolt *a* and prevents the bolt from being lost in the event of the failure of the jamb nut and pin b_2. The crosshead is placed in the slot in the adjuster rod by making the rod in two parts. The crosshead is then placed in the slot and the two parts are welded together.

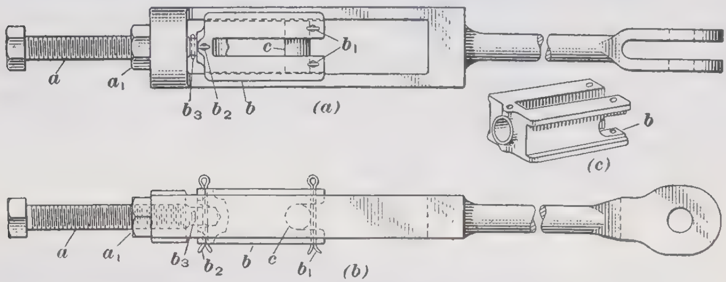


Fig. 9

The slack may be taken up by removing the key b_2, loosening the jamb nut a_1, and turning the threaded bolt to the right, and let out by turning the bolt to the left. The bolt is then turned to a position in which the key b_2 may be replaced, and the jamb nut is then tightened. If it becomes necessary to remove the slack-adjuster pull rod, as much slack as possible is let out and the two keys b_1 are removed. The crosshead is then moved to the rear until it is clear of the truck lever. The slack-adjuster pull rod may then be removed from the truck lever by disconnecting the upper end of the lever from the bracket.

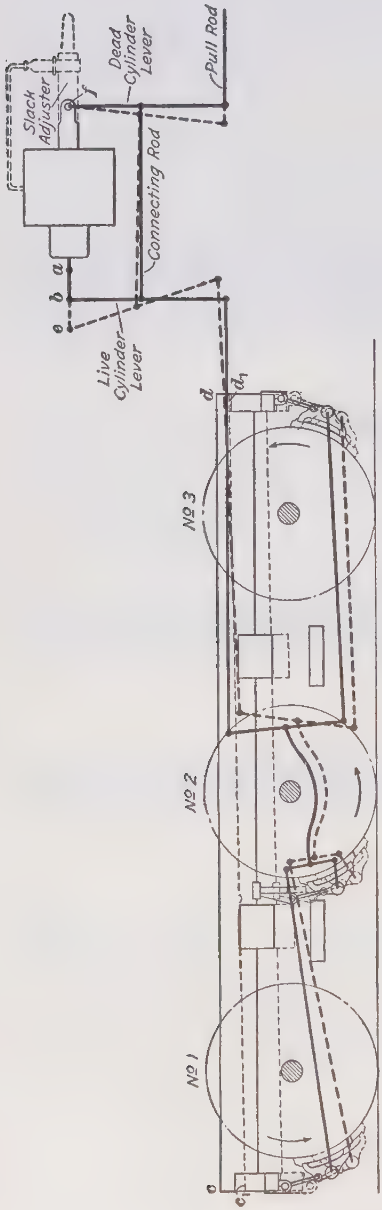


Fig. 10

TYPES OF BRAKE RIGGING COMPARED

7. Disadvantages of Single-Shoe-per-Wheel Type.—The principal objection to the single-shoe-per-wheel type of brake rigging is the tilting of the trucks and the consequent increase in piston travel and reduction in brake-shoe clearance that attends its use when the braking ratio is high. While this type of brake rigging is entirely unsuited to use on passenger cars with a high braking ratio, it can be employed satisfactorily in cases where the braking ratio is low, as on freight cars.

8. Action of Brake Shoes in Tilting Truck. The action of the brake shoes in causing the truck to tilt when the brakes are being applied, will be understood by referring to Fig. 10. This figure shows a six-wheel truck which is moving in the direction indicated by the arrow, and which has one brake shoe per wheel. It will be noted that the brake shoes and brake rigging which

are shown in their normal position by full lines, are hung considerably below the center of the wheels. This is necessary when but one brake shoe is used, because if the shoes were hung higher up the heavy unbalanced force against one side of the wheel would push the journals out of their bearings. However, there is a heavy lateral thrust on the journal boxes even with the shoes hung as shown.

The position of the brake-cylinder piston when it is in release position is shown by *a*, Fig. 10, and *b* shows the position of the piston when the brakes are applied. The effect on the brake shoe on the No. 3 wheel will be considered first. The pressure against this brake shoe when it is hung low on the wheel forces it down under the wheel with a wedging action that has a tendency to lift the wheel off the rail. The wedging action of the brake shoe is opposed by the friction between the brake shoe and the wheel which tends to move the brake shoe upwards. As the brake shoe is not pulled directly against the center of the wheel, the wedging action exceeds the friction of the brake shoe. The brake shoe and the brake rigging then move down to their dotted line positions and the truck moves from *d* to d_1.

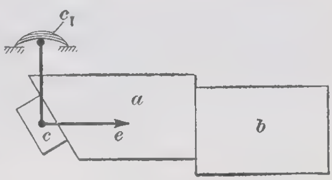


FIG. 11

The action of the brake shoe in pulling the truck down can be more readily understood by referring to Fig. 11, which shows a block *a* resting against a fixed part *b*, and a block *c* that is suspended by a hanger from a spring c_1. The block is pulled against *a* by the rod *e*. The block *c* may be compared to the brake shoe and the block *a* to the wheel. On account of the angle at which *a* is cut, the pull on the rod causes a wedging effect as well as friction between *a* and *c*. The block *c* will be pulled down, which shows that the wedging action of the block *c* is in excess of the friction between *a* and *c*.

The same action as was described at the No. 3 wheel, Fig. 10, also occurs at the brake shoes at No. 1 and No. 2 wheels, with the exception that the brake-shoe friction now assists the wedging action of the brake shoes. Therefore the brake shoes

on these wheels, as shown by their dotted outlines, will be pulled down further than on the No. 3 wheel. The left end of the truck will also move down farther, or from c to c_1. The line $c\ d$ shows the original position of the truck and the line $c_1\ d_1$ shows its position after the brake is applied. The downward movement of the truck puts a heavy overload on the equalizers, equalizer coil springs, and the axles.

9. Effect of Truck Tilting on Piston Travel.—The piston travel will increase when the truck tilts and the brake shoes move down under the wheels because the brake shoes are now moving closer to the brake cylinder. The brake-cylinder piston, instead of remaining at b, will move out to e. This movement of the piston gives a false piston travel equal to $b\ e$ and thereby lessens the pressure in the brake cylinder. If the piston travel $a\ e$ exceeds the travel permitted by the slack adjuster, the adjuster will operate and when the brakes are released will move the end f of the dead-cylinder lever outwards. The connecting-rod then pulls the live cylinder lever and point e closer to the brake cylinder and moves the brake shoes closer to the wheels.

When the brakes are applied again the same action will occur, that is, the brake shoes will pull down on the wheels and cause the piston travel to increase, and the slack adjuster will operate and bring the brake shoes closer to the wheels and thus reduce the piston travel. The final result will be that the piston travel instead of being maintained equal to $a\ b$ will become much less, or the piston, when the car is standing, may have to move only a few inches to bring the brake shoes up against the wheels. For example, if the piston travel were reduced to 3 inches and the leverage ratio is 9 to 1, the shoe clearance would be $\frac{3}{9}$, or $\frac{1}{3}$, inch, which would not be enough to keep the brake shoes clear of the wheels. When the piston travel is short it will be impossible to apply the brakes lightly without severe shocks on account of the high brake-cylinder pressure developed by the short travel.

The brake is referred to as not being flexible, when light brake applications cannot be made without causing shocks.

The foregoing shows that a single brake shoe cannot be hung low without a great loss of braking force. Neither can it be hung too high without danger of pushing the axle out from under the bearing. The reduction in shoe clearance caused by the slack adjuster suggests dispensing with the device altogether. However, were it not for the adjuster the brake-cylinder piston might move out far enough to strike the cylinder head. The operation of the slack adjuster is then as it should be and its action shows the necessity of changing the design of the brake rigging.

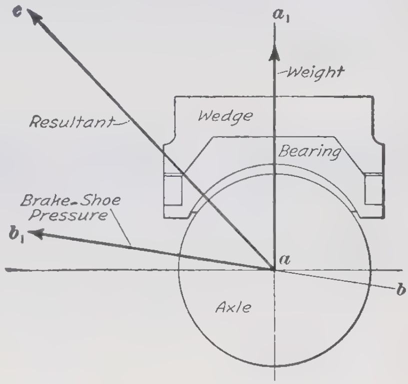
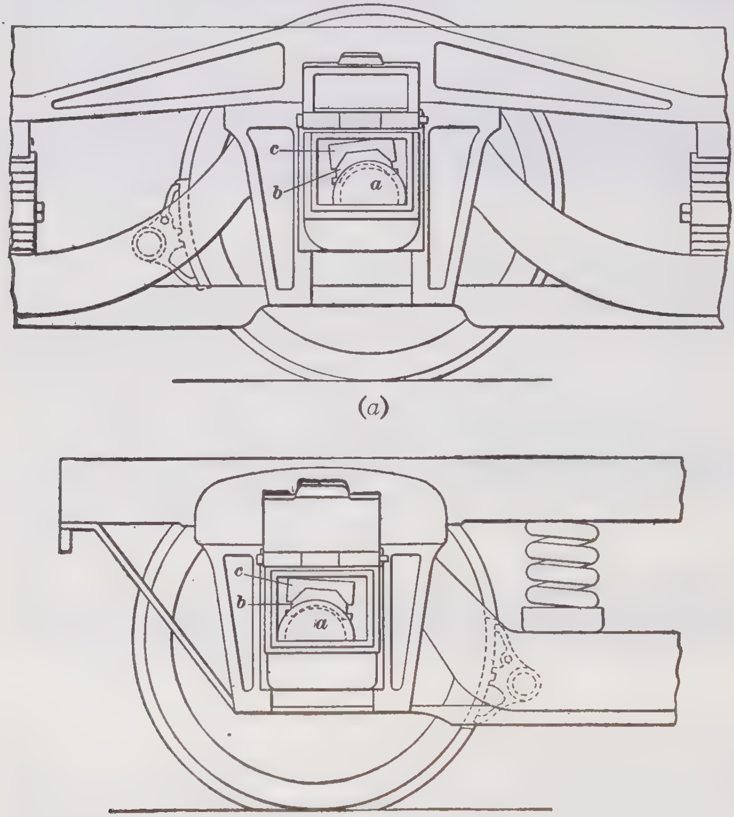


Fig. 12

10. Displacement of Journal.—When the brake shoes are hung low on the wheels, as they necessarily must be when a single brake shoe is used, there is danger of the axle journal being pushed out of its bearing when a heavy brake application is made. This can be understood by referring to Fig. 12, which illustrates a typical condition when one brake shoe is used. The downward force on the axle due to the weight is resisted by an equal and opposite upward force, which is represented by the line $a\,a_1$. The brake-shoe pressure tends to push the axle along the line $b\,b_1$ from the center of the shoe to the center of the wheel. The combined action of these forces causes the axle to be pushed by a force that acts in the direction of the line $a\,c$.

It will be noted that the line $a\,c$ passes near the outside corner of the wedge. Therefore, if the brake is applied hard the axle will tip up both the wedge and the bearing, and the axle will be forced against the journal box. This would not only cause the car to ride very roughly and the journal to overheat, but it would greatly increase the horizontal movement of the brake shoes and the false piston travel.

Views (*a*) and (*b*), Fig. 13, show the displacement of the journals, brasses, and wedges. The journal is marked *a*, the bearing *b*, and the wedge *c*. It will be noted that the journal is moved to the front of the box in Fig. 13 (*a*) and to the



(*a*)

(*b*)

Fig. 13

rear in (*b*). The brake shoe is therefore behind the wheel in Fig. 13 (*a*) and ahead of the wheel in Fig. 13 (*b*). When the journal bearing is displaced the journal pushes against the leg of the pedestal and is liable to break it.

11. Importance of Proper Design of Brake Rigging. The foregoing shows the importance of a design of brake rigging that will maintain the same piston travel under all conditions. A design which permits false travel gives rise to a great number of objectional features. For example, when the piston travel increases during an application of the brakes, the slack adjuster shortens the travel and reduces the shoe clearance. A short piston travel in turn destroys the flexibility of the brake, as light brake applications cannot be made without severe shocks.

12. Advantages of the Clasp Brake.—The principal advantage of a properly designed, manufactured, and installed type of brake rigging using two brake shoes per wheel is that there is practically no difference between the standing and the running piston travel. The reason is that the brake shoes can be located close to the horizontal center line of the wheels, because the braking forces on both sides of the wheel are balanced and there is no danger of displacing the journals. With the brake shoes hung in this manner no creeping action occurs as with the single shoe, and the brake shoes remain the same distance from the brake cylinder. The same piston travel under all conditions eliminates all the undesirable features that arise from a variable piston travel, such as reduced shoe clearance and loss of brake flexibility. Heavy overloads on the springs and equalizers and journal displacement with consequent overheating are also prevented.

An example of the superiority of the clasp-brake over the single-brake shoe in reducing false piston travel is shown in a test in which the increase in piston travel was only one-half inch from a service application of the brakes, standing, to an emergency application at 80 miles per hour. Cars equipped with a single-brake shoe under a similar test gave an increase in piston travel of 5 or 6 inches.

Another advantage of the clasp brake is the higher coefficient of friction and therefore the greater retarding force which is obtained when two brake shoes are used. The principal factor which affects the coefficient of friction under severe braking conditions is heat. When the braking force is applied to the

wheel through one brake shoe, the shoe must necessarily become much hotter than when the pressure is divided between two shoes. It has been found that the gain in the coefficient of friction with the clasp brake is over 5 per cent. The brake-shoe wear with two brake shoes will also be less than when one is used.

DIFFERENT DESIGNS OF BRAKE RIGGING

13. Conditions Affecting Design.—The design of the brake rigging as far as the arrangement at the brake cylinder is concerned, depends on whether the air-brake equipment consists of one or two brake cylinders. Two types of brake equipment are used on freight cars, the ordinary type of brake, also known as the single-capacity brake or empty-car brake, on account of the same braking force being used under all conditions of loading; and the empty and load brake, in which the breaking force varies. As the former uses one brake cylinder and the latter two, the design of the brake rigging necessarily differs.

The PM and LN equipments are one brake-cylinder equipments and the brake rigging, therefore, does not differ materially from that of the empty car brake. In cases where the weight of the car is such as to require a braking force greater than the capacity of one brake cylinder with the proper leverage ratio, two air-brake equipments known as the double PM and the double LN are used. The brake rigging for the double equipments consists of a separate set of brake rigging for each truck and does not differ from the rigging used with the single equipment. The PC equipment and some of the earlier UC equipments use two brake cylinders, both of which are connected to the same brake rigging, and the rigging, therefore, differs from that used with other brake equipments. The brake rigging for locomotives differs materially from that used on freight or passenger cars.

14. Brake Rigging for Freight Equipment.—The brake rigging used with a single-capacity freight brake has

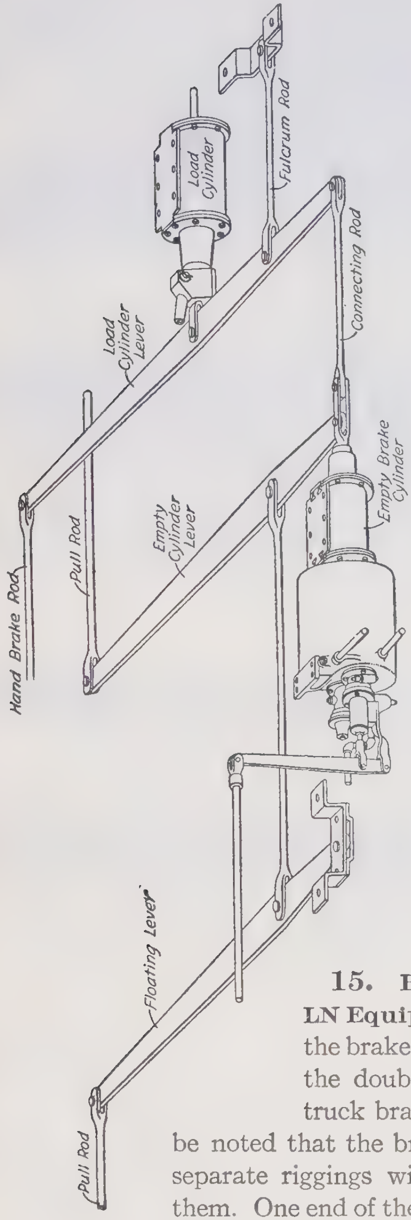


Fig. 14

already been illustrated and explained when considering Fig. 1. The brake rigging used with the empty and load brake is shown in Fig. 14. The brake rigging for the trucks is the same as is used with the single-capacity brake, and this part of the rigging is, therefore, omitted. The empty-cylinder lever is connected to the load-cylinder lever by a connecting-rod and the fulcrum rod forms a fulcrum for the latter lever. When the load cylinder is cut in, the force in this cylinder is transmitted to the push rod of the empty-brake cylinder and acts with the force that is being applied by the empty brake cylinder to the empty brake-cylinder lever.

15. Brake Rigging for Double LN Equipment.—In Fig. 15 is shown the brake rigging applied to a car with the double LN equipment with the truck brake rigging omitted. It will be noted that the brake rigging consists of two separate riggings with no connection between them. One end of the live cylinder lever works in

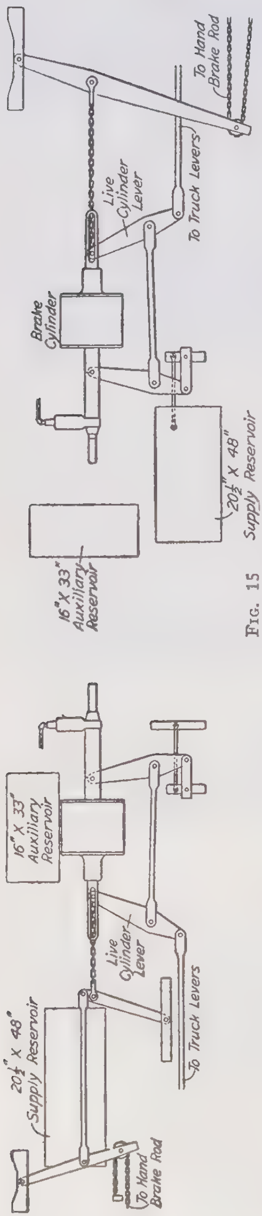


Fig. 15

a slot in the push rod, thereby enabling the hand-brake to be applied without moving the brake-cylinder piston.

16. Brake Rigging for PC Equipment.—In Fig. 16 is shown the part of the brake rigging adjacent to the brake cylinders, that is used with the PC equipment. With this equipment the emergency-brake cylinder is only used in an emergency application. The cylinder levers are attached to the pull rods by connecting links. The end of the cylinder lever which is connected to the crosshead of the service cylinder moves outwards when the brake is applied and draws each of the pull rods toward the brake cylinder. The end of the cylinder lever which is connected to the emergency cylinder moves outwards at this time in the slotted crosshead without moving the piston. When an emergency application is made all the cylinder levers transmit a pull to the pull rods, and the braking force is doubled, provided the brake cylinders are of the same size.

A hand-brake rod is connected to each end of the hand-brake lever and the lever is pinned to a fulcrum that is bolted to the car. The hand-brake operates in harmony with the air brake. This means that the application of the hand-brake operates the brake rigging in the same way as the air brake operates it. This is a legal requirement of the Interstate Commerce

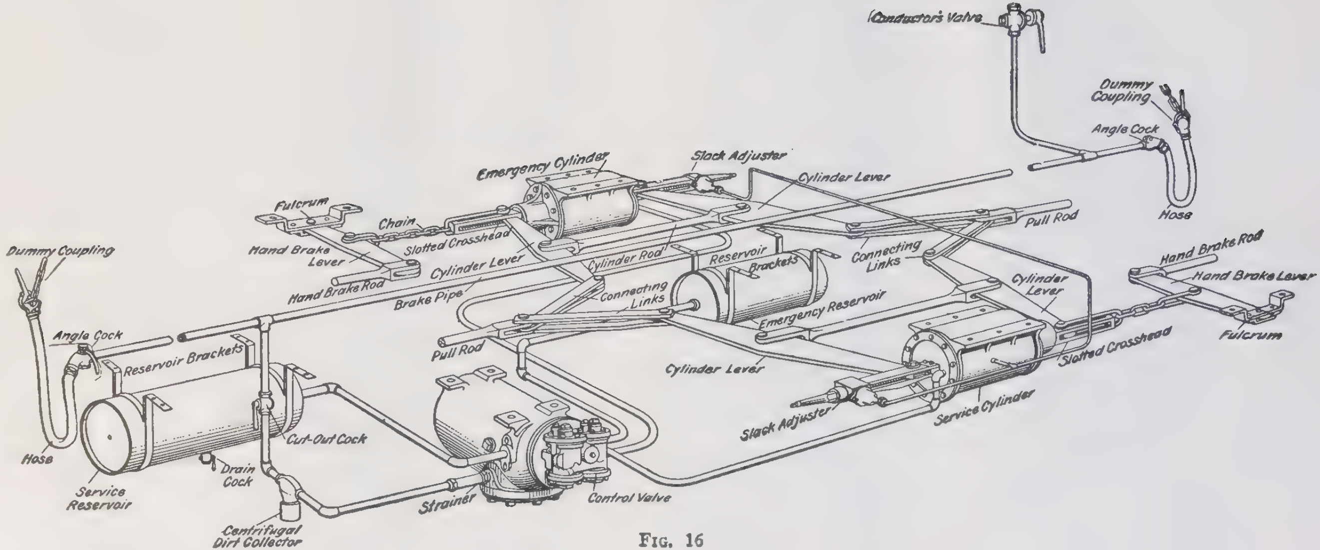

Conductor's Valve
Dummy Coupling
Angle Cock
Hose
Emergency Cylinder
Slack Adjuster
Cylinder Lever
Fulcrum
Chain
Pull Rod
Slotted Crosshead
Dummy Coupling
Hand Brake Lever
Cylinder Lever
Cylinder Rod
Reservoir Brackets
Connecting Links
Hand Brake Rod
Hand Brake Rod
Hand Brake Lever
Brake Pipe
Connecting Links
Cylinder Lever
Emergency Reservoir
Angle Cock
Reservoir Brackets
Pull Rod
Fulcrum
Slotted Crosshead
Cylinder Lever
Service Cylinder
Slack Adjuster
Cut-Out Cock
Hose
Drain Cock
Service Reservoir
Strainer
Control Valve
Centrifugal Dirt Collector

Fig. 16

Commission. The hand-brake does not operate in harmony with the air brake when the live cylinder lever moves toward the brake cylinder when the hand-brake is applied.

BRAKE-RIGGING CALCULATIONS

17. Reason for Figuring Leverage.—The principal reason for figuring leverage is to find the nominal braking ratio. It can then be seen whether the braking ratio is more or less than it should be for the service in which the car is engaged. When it is desired to find the braking ratio, one starts with a known size of brake cylinder and with a sketch of the brake rigging which shows the length of all the levers. The levers should be carefully measured, the measurements being taken between the centers of the pins or pin holes. The length of the lever arms is usually taken to the nearest $\frac{1}{4}$ inch. When figuring leverage one lever is taken at a time and, therefore, the rules which have already been given can be used for the calculation of a single lever.

As the pressure of the air in the brake cylinder is the force which is applied to the brake rigging through the brake-cylinder piston, the first step that must be taken when figuring leverage, is to find how to calculate the brake-cylinder force.

18. Force Exerted in Brake Cylinder.—The brake-cylinder force, or brake-cylinder value, as it is usually called, is equal to the area of the brake piston in square inches multiplied by the air pressure in pounds per square inch. The area of the brake piston is found by multiplying the diameter by the diameter, and then by .7854. If the diameter of a brake piston is 10 inches, the area is equal to $10 \times 10 \times .7854 = 78.5$ square inches.

Table I gives the brake-cylinder values for different pressures as well as the area of the brake-cylinder pistons of different diameters.

TABLE I

BRAKE-CYLINDER VALUES

Diameter	Area in Sq. In.	Force in Pounds			
		50 Lb. per Sq. In.	60 Lb. per Sq. In.	85 Lb. per Sq. In.	100 Lb. per Sq. In.
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
8″	50.1	2,500	3,000	4,250	5,010
10″	78.5	3,925	4,700	6,700	7,850
12″	113.1	5,650	6,800	9,600	11,300
14″	154.0	7,700	9,250	13,100	15,400
16″	201.0	10,050	12,050	17,100	20,100
18″	254.0	12,700	15,250	21,600	25,400
2– 8″	100.5	5,050	6,050	8,550	10,050
2–10″	157.1	7,850	9,400	13,400	15,710
2–12″	226.0	11,300	13,600	19,200	22,600
2–14″	308.0	15,400	18,500	26,200	30,800
2–16″	402.0	20,100	24,100	34,200	40,200
2–18″	508.0	25,400	30,500	43,200	50,800

The brake-cylinder value with a pressure of 86 pounds can be obtained by adding columns 2 and 5, because a pressure of 1 pound per square inch will give the figures shown in column 2.

FINDING THE BRAKING RATIO

19. Rules for Finding the Braking Ratio.—The rules bv which all problems relating to levers can be solved were given in *Foundation Brake Rigging*, Part 1. It is only necessary, when it is required to find the braking ratio, to use two of these rules, which are repeated here for convenience.

Rule I.—*To obtain the force at a point between the ends of a lever, add together the forces on the ends. To obtain the force at one end, subtract the force at the other end from the force between the ends.*

Rule II.—*To find the delivered force, multiply the force applied by the length of the lever between the applied force and the fulcrum, and divide by the length of the lever between the delivered force and the fulcrum.*

20. Finding the Braking Ratio.—Suppose that it is required to find the braking ratio of a freight car weighing 52,000 pounds when empty. The braking ratio of such a car should be 60 per cent.; that is, 60 per cent. of the empty weight should be used as the brake-shoe pressure, or the braking force.

The levers of the foundation brake rigging are carefully measured and a sketch is made of the rigging, as shown in Fig. 17. The diameter of the brake cylinder is 10 inches, and the brake-cylinder force will be taken as 3,900 pounds instead of the calculated pressure of 3,925 pounds. When fractions occur in the calculations that follow, they are dropped, and whole numbers only are used. The points which are taken as fulcrums are marked *f*. The calculation of the braking ratio may be divided into successive steps, as follows:

21. Force Delivered to Top Rod by Live Cylinder Lever.—The force which is delivered to the top rod by the lower end of the live cylinder lever may be found by applying rule II, and it is, therefore, equal to

$$\frac{3{,}900 \times 12}{24} = 1{,}950 \text{ pounds}$$

22. Force Delivered to Brake Beam by Live Truck Lever.—A force of 1,950 pounds is applied by the top rod to the end of the live truck lever on the left truck. The force which the live truck lever delivers to the brake beam is equal to $\frac{1{,}950 \times 24}{6} = 7{,}800$ pounds. The braking force on each of the wheels is then equal to 3,900 pounds.

23. Force Delivered by Live Truck Lever to Bottom Rod.—The force delivered by the live-truck lever to the bottom rod is equal to $7{,}800 - 1{,}950 = 5{,}850$ pounds. This is the force which is applied to the lower end of the dead truck lever by the bottom rod.

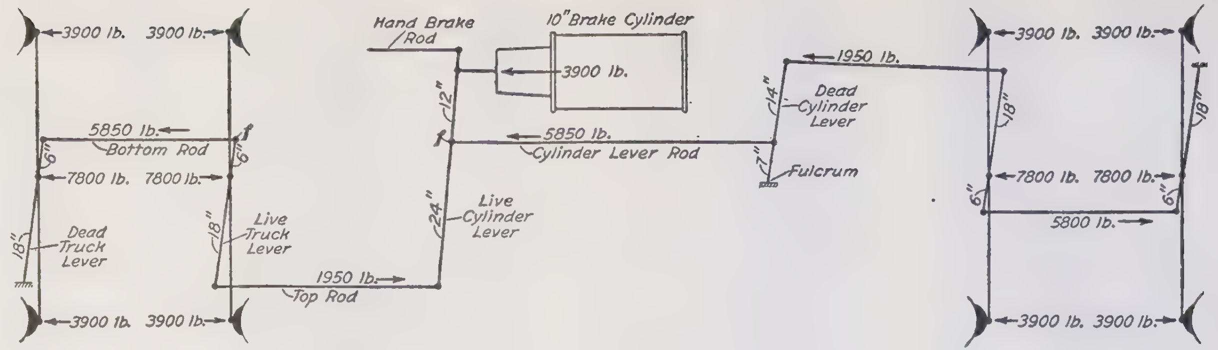

3900 lb.
3900 lb.
Hand Brake Rod
10" Brake Cylinder
3900 lb.
5850 lb.
Bottom Rod
7800 lb.
7800 lb.
6"
6"
12"
5850 lb.
Cylinder Lever Rod
1950 lb.
14"
Dead Cylinder Lever
7"
Fulcrum
18"
Dead Truck Lever
18"
Live Truck Lever
24"
Live Cylinder Lever
1950 lb.
Top Rod
3900 lb.
3900 lb.
7800 lb.
7800 lb.
5800 lb.

Fig. 17

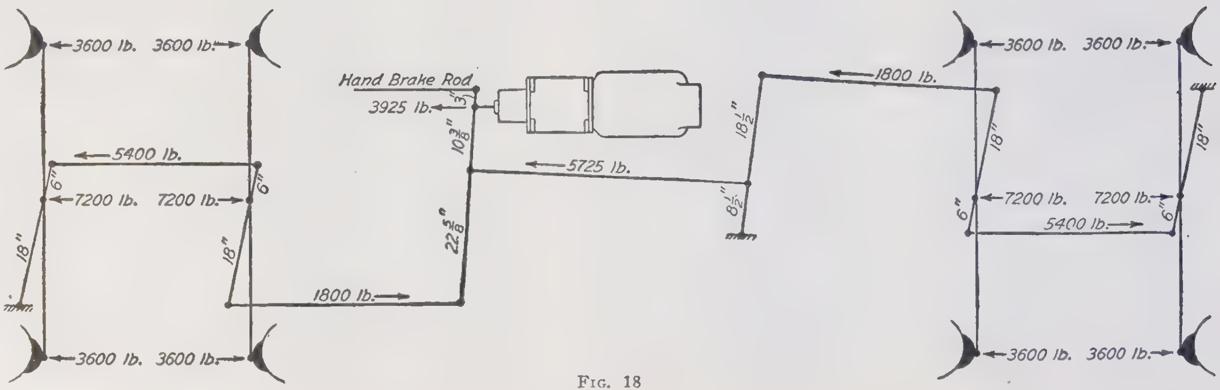

3600 lb.
3600 lb.
Hand Brake Rod
3925 lb.
3"
$10\frac{3}{8}$"
1800 lb.
$18\frac{1}{2}$"
5400 lb.
5725 lb.
$8\frac{1}{2}$"
7200 lb.
7200 lb.
6"
6"
18"
18"
$22\frac{5}{8}$"
1800 lb.
5400 lb.

Fig. 18

24. Force Delivered to Brake Beam by Dead Truck Lever.—The force delivered to the other brake beam by the dead truck lever, taking the upper end as the fulcrum, is

$$\frac{5{,}850 \times 24}{18} = 7{,}800 \text{ pounds}$$

The braking force on each of the wheels of this truck is then 3,900 pounds, or it is the same as that on the other truck

25. Force on Fulcrum of Live Cylinder Lever.—The force on the fulcrum of the live cylinder lever is equal to $3{,}900 + 1{,}950 = 5{,}850$ pounds. This is the force which is applied to the end of the dead cylinder lever through the cylinder lever rod.

26. Calculating the Forces on Other Truck.—The forces which act upon the brake beams of the right-hand truck are figured in the same way as on the left-hand truck, and the calculations, therefore, need not be repeated.

27. Total Brake-Shoe Pressure.—The total brake shoe pressure equals

$$7{,}800 \times 4 = 31{,}200 \text{ pounds}$$

28. Braking Ratio.—The braking ratio is equal to the braking force (31,200 pounds) divided by the empty weight of the car (52,000 pounds) or .60, or 60 per cent. The braking ratio of the car is, therefore, correct.

29. Total Leverage Ratio.—The total leverage ratio is the total brake-shoe pressure (31,200 pounds) divided by the cylinder force (3,900 pounds). In this case the ratio is 8.

30. Fulcrum Points.—The fulcrum points which are taken are not the ones that must necessarily be used. For example, the fulcrum point of the live truck lever was assumed to be at *f*. However the point at which this lever is connected to the brake beam may also be taken as the fulcrum point. The application of rule II will then give the force which is delivered to the end of the lever. Thus,

$$\frac{1{,}950 \times 18}{6} = 5{,}850 \text{ pounds}$$

and from rule I, the force on the brake beam is

$$1{,}950 + 5{,}850 = 7{,}800 \text{ pounds}$$

Likewise the fulcrum of the dead cylinder lever may be assumed to be at the brake beam or at the upper end. If the fulcrum is taken at the brake beam, the force delivered to the upper end of the lever equals $\frac{5{,}850\times 6}{18}=1{,}950$ pounds. The force on the brake beam then is $1{,}950+5{,}850=7{,}800$ pounds. It may also be assumed that the fulcrum of the live cylinder lever is at the end instead of between the ends.

31. Locating the Middle Hole in the Live-Cylinder Lever.—Suppose it is required to find whether the middle hole in the live cylinder lever of a freight car is located at the correct point. The empty weight of the car is 48,000 pounds, the brake cylinder is 10 inches in diameter, and the measurement of the levers gives the lengths shown in Fig. 18.

32. Rules That Are Used.—The rules that are used when checking the length of the arms of the live-cylinder lever, are given in the previous Section but are repeated here for convenience.

Rule III.—*The applied force is equal to the delivered force multiplied by the length of the lever between the delivered force and the fulcrum, divided by the length of the lever between the applied force and the fulcrum.*

Rule IV.—*To find the length of the lever between the applied force and the fulcrum, multiply the delivered force by the total length of the lever, and divide by the sum of the applied and delivered forces. To find the length of the lever between the delivered force and the fulcrum, multiply the applied force by the length of the lever and divide by the sum of the applied and delivered forces.*

33. Order of Calculations.—The following order will be observed when the calculations which involve the location of the middle hole of the live-cylinder lever are taken up.

34. Total Braking Force or Brake-Shoe Pressure. The total braking force or brake-shoe pressure is equal to the empty weight of the car multiplied by the braking ratio. Thus, $48{,}000 \times .60 = 28{,}800$ pounds.

35. Force on Brake Beams.—The force on each one of the brake beams is equal to $\frac{28{,}800}{4} = 7{,}200$ pounds. This is the force which is delivered by the dead-truck lever.

36. Force Applied by Bottom Rod.—The force which must be applied to the dead-truck lever by the bottom rod to produce a force of 7,200 pounds on the brake beam may be found from rule III and is as follows:

$$\frac{7{,}200 \times 18}{24} = 5{,}400 \text{ pounds}$$

This is the force delivered to the bottom rod by the live-truck lever.

37. Force Applied to Live-Truck Lever.—The force which is applied to the live-truck lever by the top rod is equal to $7{,}200 - 5{,}400 = 1{,}800$ pounds. This is the force which acts on the lower end of the live-cylinder lever.

38. Length of Arms of Live-Cylinder Lever.—The length of the arms of the live-cylinder lever or the location of the fulcrum point may be found from rule IV. The length of the lever arm between the applied force and the fulcrum is

$$\frac{1{,}800 \times 33}{1{,}800 + 3{,}925} = 10\tfrac{3}{8} \text{ inches}$$

The length of the lever arm between the delivered force and the fulcrum is

$$\frac{3{,}925 \times 33}{1{,}800 + 3{,}925} = 22\tfrac{5}{8} \text{ inches}$$

The live cylinder lever is, therefore, correctly proportioned.

CHECKING THE BRAKE RIGGING

39. The brake rigging, if properly designed, will transmit the same braking force to each wheel. It is then important to be able to check quickly the brake rigging to see whether it is properly designed. The brake rigging may be checked by obtaining the lengths of the lever arms between the centers of the pins or pinholes and then seeing whether the lever arms of all the truck levers and the cylinder levers are in the same proportion.

It will be noted that the term *lever arm* as here used means the length of the arms between the pinholes and does not mean the length of the arms between the applied and delivered forces and the fulcrum. Two levers are said to be in the same proportion if the same result is obtained when the length of the long arm of each is divided by the length of the short arm.

40. In Fig. 17, for example, the live- and the dead-cylinder levers are in the same proportion, because the same number, or 2, is obtained when the length of the long arm of each is divided by the length of the short arm. These levers are then said to be *2-to-1 levers.* All the truck levers are also in the same proportion, because each is a 3-to-1 lever. The brake rigging is, therefore, properly designed, because all levers of the same kind are in the same proportion and an equal braking force will be transmitted to each wheel.

It is not necessary for levers of the same kind to be of the same length. They may be of unequal lengths, provided the proportion remains the same. Thus, one truck lever may be 25 inches long and the other 30 inches long. The long arm of the first one is 20 inches and the short arm is 5 inches long. The long arm of the second lever is 24 inches and the short arm is 6 inches long. The levers are in the same proportion because each is a 4-to-1 lever.

41. Effect of an Improperly Proportioned Lever on Braking Force.—The effect on the braking force of substituting a lever which is not proportioned the same as the other

levers will now be explained. Let it be assumed, that one of the live truck levers in Fig. 17 is replaced by a lever 25 inches long, with one arm 20 inches long, and the short arm 5 inches long. This lever is then a 4-to-1 lever instead of a 3-to-1 lever, like the others. The following calculation will show the change that is made in the braking force by the substitution of this lever.

The force delivered to the first brake beam is

$$\frac{1{,}950 \times 25}{5} = 9{,}750 \text{ pounds}$$

The force which is delivered to the bottom rod is equal to $9{,}750 - 1{,}950 = 7{,}800$ pounds. The force which is delivered to the other brake beam is equal to $\frac{7{,}800 \times 24}{18} = 10{,}400$ pounds. The braking forces on the two pairs of wheels are unequal and the total braking force on the truck is $20{,}150 - 15{,}600$, or 4,550 pounds more than it should be.

However, a truck lever of a different length may be substituted if the proportion is the same as the old lever. Thus, a lever 28 inches long may be used if one arm is 21 inches long and the other arm is 7 inches long, because this is also a 3-to-1 lever. It is, therefore, necessary for all the truck levers and also the two cylinder levers to be in the same proportion.

42. Finding Braking Ratio With Clasp Brake.—In Fig. 8 (*b*) is shown the outline of a clasp brake applied to a six-wheel passenger-car truck. The brake-rigging arrangement is shown on only one side of the truck, as the arrangement is the same on the other side. The car weighs 147,860 pounds. The brake cylinder is 18 inches in diameter, and the brake-cylinder value is 15,250 pounds, with a pressure of 60 pounds. The lengths of the levers are as shown. The points taken as fulcrums are marked *f*.

The braking ratio can be found from rules I and II given in Art. 19. When these rules are applied it will be noted that the values obtained in some cases are changed a few pounds so as

to have them all the same. It will be found convenient to arrange each step in the following order:

43. Force Delivered by Cylinder Lever to Horizontal Equalizer Connecting-Rod.—The force delivered by the lower end of the live cylinder lever a to the horizontal equalizer connecting-rod a_1 is

$$\frac{15{,}250 \times 20\frac{1}{2}}{15\frac{1}{2}} = 20{,}170 \text{ pounds}$$

This force is applied to the middle of the horizontal equalizer b and, therefore, a force of one-half this amount, or 10,085 pounds, is transmitted by this equalizer to the truck connecting-rod b_1 and the upper end of the first truck lever.

44. Force Delivered by Truck Lever to Hanger Lever. The force delivered by the truck lever through link d to the lower end of the hanger lever d_1 is

$$\frac{10{,}085 \times 6\frac{1}{2}}{20\frac{3}{8}} = 3{,}216 \text{ pounds}$$

45. Force Delivered to Brake Shoe.—The force delivered to the first brake shoe is

$$\frac{3{,}216 \times 18\frac{3}{4}}{10\frac{7}{8}} = 5{,}545 \text{ pounds}$$

46. Force Delivered to Second Truck Lever by Bottom Truck Rod.—The force delivered to the second truck lever by the bottom truck rod c is $10{,}085 + 3{,}216 = 13{,}300$ pounds.

47. Force Delivered to Hanger Lever by Truck Lever. The force delivered to the second hanger lever d_3 through the link d_2 is

$$\frac{13{,}300 \times 6\frac{1}{2}}{26\frac{7}{8} \text{ (total length)}} = 3{,}216 \text{ pounds}$$

48. Force Delivered to Brake Shoe.—The force delivered to the second brake shoe is

$$\frac{3{,}216 \times 18\frac{3}{4}}{10\frac{7}{8}} = 5{,}545 \text{ pounds}$$

49. Force Applied to Top Truck Rod.—The force applied to the top truck rod is $13{,}300-3{,}216=10{,}085$ pounds.

50. Braking Force Delivered to Other Wheels.—The calculation of the braking force delivered to the other wheels is merely a repetition of the calculations already made, and it is therefore unnecessary to repeat them. The calculation of the braking force on the opposite side of the truck may be omitted for the same reason.

51. Calculating Braking Force on Other Truck.—It is unnecessary to calculate the braking force on the other truck, after it has been shown how to obtain the force which is delivered to the pull rod by the dead-cylinder lever. The force acting on the cylinder-lever connecting-rod is

$$20{,}170+15{,}250=35{,}420 \text{ pounds}$$

The force delivered by the lower end of the dead cylinder lever to the pull rod of the other truck is

$$\frac{35{,}420\times 20\frac{1}{2}}{36}=20{,}170 \text{ pounds}$$

52. Total Braking Force, or Brake-Shoe Pressure. The total braking force, or brake-shoe pressure, is equal to the force exerted against a wheel by one brake shoe (5,545 pounds) multiplied by the number of brake shoes (24). The total braking force is then about 133,080 pounds.

53. Service-Braking Ratio.—The service-braking ratio is equal to the service-braking force (133,080 pounds) divided by the weight of the car (147,860 pounds). The service braking ratio is then .90, or 90 per cent.

54. Emergency-Braking Ratio.—The emergency-braking ratio can be figured in the same way as the service-braking ratio. A brake-cylinder pressure of 100 pounds to the square inch, which is obtained in emergency with the LN and UC equipments, gives a brake-cylinder force of 25,400 pounds. (See Table I.) This force gives a braking force of about 221,760

pounds when it is transmitted through the brake rigging to the brake shoes. The emergency-braking ratio is then

$$\frac{221,760}{147,860}=1.5, \text{ or } 150 \text{ per cent.}$$

LOCOMOTIVE BRAKE RIGGING

55. Names of Parts.—In Fig. 19 (*a*) is shown the arrangement of the brake rigging as applied to a Santa Fe type of locomotive, and in view (*b*) is shown the length of the various levers and the stresses on the different points. In view (*a*) the frame of the locomotive on the right side is removed so as to show the rigging more clearly. Some parts of the brake rigging on the left side of the locomotive cannot be seen in this view, but this is unimportant, as these parts are the same as on the right side. Reference letters are applied to only one side of the brake rigging. The names of the principal parts of the brake rigging are as follows: a, bell crank; a_1, the shaft; b, pull rod with slack adjuster b_1; b_2, second pull rod; b_3, third pull rod; b_4, back pull rod; c, main equalizer; c_1, middle equalizer; c_2, back equalizer; d, brake beam; d_1, brake head; d_2, brake shoe; e, intermediate lever; e_1, pull connection; f, return hanger lever; g, hanger lever; h, strap link.

56. Arrangement of Parts.—The brake rigging shown in Fig. 19 (*a*) consists of two separate riggings, one operated by the two forward brake cylinders, and the other by the two rear brake cylinders. The reason for using four brake cylinders is that the braking force necessary on a heavy locomotive is more than two brake cylinders can develop. The two forward brake cylinders are 14 inches in diameter and 10 inches long. The brake-cylinder value is 7,700 pounds with a brake-cylinder pressure of 50 pounds to the square inch. The rear brake cylinders have a diameter of 12 inches and develop a force of 5,650 pounds with a pressure of 50 pounds to the square inch. The brake shoes hang behind the wheels so that there will be no pull downwards on the driver springs when the brakes are applied and the locomotive is moving ahead. The four bell-cranks a the back ends of which are pinned to the brake-cylinder

pistons, turn freely on their shafts a_1, which are connected to the frames of the engine by brackets not shown. The bellcranks are prevented from moving sidewise on the shafts by collars a_2. which are held in place by setscrews. The parts of the shafts on which the bellcranks turn are lubricated through the oil cups shown. The front pull rods b, which have a slack-adjuster arrangement b_1 where they connect to the bellcranks, are pinned to the main equalizers c, which in turn are pinned to a link c_3 on the brake beam. The second pull rods b_2 are pinned between the ends of the middle equalizers c_1. One end of these equalizers is pinned to the strap links h, which are pinned to the brake beam, and the other end is pinned to the third pull rod b_3. These pull rods are pinned directly to the third brake beam.

57. The front ends of the back pair of pull rods b are pinned to the bellcranks and their back ends are connected to the intermediate equalizers e by a slack-adjuster arrangement. The lower end of these equalizers are connected by the pull connections e_1 to the back equalizers c_2, which are connected to the brake beams by the links c_4. The outer ends of the back equalizers c_2 are pinned to the back pull rods b_4, which in turn are pinned to the back brake beam. The outer ends of the brake beams pass through holes in the return hanger levers f and the hanger levers g. The levers are held in place on the brake beams by cotter keys f_3 with the exception of the third and fifth brake beams, on which nuts f_4 are used. Collars are sometimes placed between the cotter keys and the levers to prevent any tendency for the keys to be sheared off. The brake shoes, with the exception of the back pair, are connected by pins f_1 to lugs cast on the inside of the return hanger levers. The upper ends of the hanger levers turn freely in the brackets f_2 and g_1, which are bolted to the frame of the engine.

Rod supports not shown in this view prevent any part of the brake rigging, if it should break, from falling on the track. Balance springs keep the brake shoes in their proper relation to the wheels.

58. The construction of the slack adjuster is as follows: The end of the front pull rod b_3 is slotted. A crosshead b_5 is

placed in this slot and is held in position by a pin b_6 which passes through the crosshead and both sides of the bellcrank. The inner end of the threaded adjuster rod b_7 bears against the front end of the crosshead. A jamb nut b_8 serves to keep the rod from turning. The arrangement for taking up the slack is the same on the rear pull rods as on the front rods. The slack is taken up by slacking off on the jamb nut and turning the adjuster rod to the right by applying a wrench to the square end. This draws the pull rod forward as the slot in it is longer than the crosshead. All the adjuster rods should be turned the same amount, after which all jamb nuts should be tightened.

59. Calculating the Braking Ratio.—Reference will be made to Fig. 19 (*b*) when calculating the braking ratio. The locomotive to which the brake rigging is applied has a weight of 300,000 pounds on the drivers, and it is required to find the braking ratio when the brake-cylinder pressure is 50 pounds per square inch.

First it is necessary to find the braking force or the shoe pressure, which can be done by applying the rules given in connection with the braking ratio of cars. It is necessary to calculate the braking force only on one side of the locomotive, as the braking force on the other side is the same. It will be found more convenient to reduce to inches the measurements which are shown in feet. The points on the different levers considered as fulcrums are marked *f*. It will be noted when calculating the forces that the results obtained do not agree exactly with the forces shown in view (*b*). However, the difference in all cases is so small that the odd numbers are dropped and whole numbers are used as shown in view (*b*). The dimensions on the hanger levers on the left side show their total length, and on the right side the length of these levers is shown between the pinholes.

60. The force applied to the main equalizer through the bellcrank and the pull rod is

$$\frac{7{,}700 \times 39}{7\frac{11}{16}} = 39{,}000 \text{ pounds}$$

The force applied to the brake beam is

$$\frac{39{,}000 \times 4\tfrac{1}{2}}{13\tfrac{1}{2}} = 13{,}000 \text{ pounds}$$

The force transmitted to the brake shoe is

$$\frac{13{,}000 \times 41\tfrac{1}{2}}{36} = 15{,}000 \text{ pounds}$$

The force applied to the middle equalizer is 39,000 − 13,000 = 26,000 pounds, and as this force is applied to the middle of the equalizer, a force of 13,000 pounds will be applied to the brake beam. It is unnecessary to show how to obtain the brake-shoe pressure at this brake beam, as the same calculation is used as was used at the first brake beam. For this reason the calculations for the third and fourth brake shoes are also omitted.

The force delivered by the second brake cylinder through the bellcrank and pull rod to the intermediate equalizer is

$$\frac{5{,}650 \times 29}{6} = 27{,}300 \text{ pounds}$$

The force delivered by the intermediate equalizer to the back equalizer is

$$\frac{27{,}300 \times 30\tfrac{1}{2}}{36} = 23{,}000 \text{ pounds}$$

The force delivered to the brake beam is

$$\frac{23{,}000 \times 11\tfrac{1}{2}}{20\tfrac{3}{8}} = 13{,}000 \text{ pounds}$$

The force applied to the fourth brake shoe can be found in the same manner as for the first brake shoe, and is 15,000 pounds. The back pull rod transmits a force of 23,000 − 13,000 = 10,000 pounds to the back brake beam. The force delivered to the back brake shoe is

$$\frac{10{,}000 \times 28}{18\tfrac{3}{4}} = 15{,}000 \text{ pounds}$$

61. Braking Ratio.—The total braking force is $15{,}000 \times 10 = 150{,}000$ pounds, and the weight on the drivers is 300,000 pounds. The braking ratio, therefore, is

$$\frac{150{,}000}{300{,}000} = .50, \text{ or } 50 \text{ per cent.}$$

CALCULATIONS INVOLVING AIR PRESSURES

VOLUME OF CYLINDERS AND RESERVOIRS

62. Volume of a Brake Cylinder.—The volume of a brake cylinder may be found by applying the following rule:

Rule.—*To find the volume of a brake cylinder in cubic inches, multiply the cross-sectional area of the cylinder, in square inches, by the piston travel, in inches.*

EXAMPLE.—What is the volume of a 10-inch brake cylinder having an 8-inch piston travel?

SOLUTION.—The area of the brake cylinder is equal to the diameter multiplied by the diameter and by .7854, or to 78.5 sq. in. Hence, the volume of the brake cylinder is $78.5 \times 8 = 628$ cu. in. Ans.

The volume of an auxiliary reservoir or of a main reservoir may be found by the same rule, with the exception that the cross-sectional area is multiplied by the inside length, in inches. The volume of a brake cylinder is greater than the amount calculated by the above rule, for the reason that there is an extra volume that the rule does not take into consideration. In freight equipment, the volume of the auxiliary tube and the cylinder clearance (the space between the brake-cylinder piston and the end of the auxiliary when the piston is in the position it assumes when the brake is released) is not considered, while in passenger equipment, the volume of the passage in the brake-cylinder head and the cylinder clearance must be added to the cylinder volume. Usually about 48 cubic inches are added to the calculated volume of a brake cylinder to make up for cylinder clearance, etc.

In Table II the volumes of the standard brake cylinders are given, due allowance having been made for cylinder clearance, etc.

TABLE II

VOLUMES OF AIR-BRAKE CYLINDERS

Size of Cylinder Inches	Piston Travel Inches	Volume Cubic Inches
8	8	450
10	8	675
12	8	950
14	8	1,280
16	8	1,650
18	8	2,085

If the rule for the volume of a cylinder be applied for a piston travel of 1 inch, it will be found that the number of cubic inches the volume of a brake cylinder will change for each increase or decrease of piston travel, is numerically equal to the area of the cylinder. For example, the volume of an 8-inch cylinder will change $50\frac{1}{4}$ cubic inches for every 1 inch of change in the piston travel; that of a 10-inch cylinder will change 78.5 cubic inches; that of a 12-inch cylinder, 113 cubic inches; and so on.

VOLUME OF AUXILIARY RESERVOIR

63. Volume of Freight-Car Auxiliary Reservoir. The volume of the auxiliary reservoir used with an 8-inch brake cylinder is 1,620 cubic inches, and when a 10-inch brake cylinder is used, the volume of the auxiliary reservoir is 2,440 cubic inches. The auxiliary reservoirs used with freight equipment are cast iron, and the reservoirs used with passenger equipment are of riveted and welded construction.

64. Volumes of Auxiliary Reservoirs Used With Passenger-Car Equipments.—Tables III, IV, and V give

the volumes of the auxiliary reservoirs which are used with the different types of passenger equipment and also the sizes of the brake cylinders. The first number in the dimensions is the diameter and the second number is the length.

TABLE III

BRAKE CYLINDERS AND RESERVOIRS FOR PM AND LN PASSENGER-CAR BRAKE EQUIPMENT -- SINGLE BRAKE-CYLINDER INSTALLATION

Brake Cylinders	Auxiliary Reservoirs for Use With PM and LN Equipments		Supplementary Reservoirs for Use With LN Equipment Only	
Size Inches	Size Inches	Volume Cu. In.	Size Inches	Volume Cu. In.
10×12	12×27	2,450	16 ×33	5,724
12×12	12×33	3,088	16 ×48	8,577
14×12	14×33	4,476	20½×36	10,158
16×12	16×33	5,724	20½×48	14,003
18×12	16×42	7,436	22½×54	18,967

The same sizes of reservoirs and brake cylinders are used with the double brake-cylinder installation, or when each truck has a separate equipment. Such brake equipments are referred to as double PM or double LN equipments. The double brake equipments are used when the brake cylinder is 12×12 inches and upwards.

According to Table III, the auxiliary reservoirs and brake cylinders are so proportioned that with 70 pounds brake-pipe pressure there is obtained for service applications from a 20-pound reduction an equalized brake-cylinder pressure of 50 pounds, with an 8-inch piston travel.

TABLE IV

BRAKE CYLINDERS AND RESERVOIRS FOR PC PASSENGER CAR BRAKE EQUIPMENT

Brake Cylinders	Service Reservoirs		Emergency Reservoirs	
Size Inches	Size Inches	Volume Cu. In.	Size Inches	Volume Cu. In.
14×12	16 ×48	8,577	16 ×42	7,436
16×12	$20\frac{1}{2}$×36	10,158	16 ×48	8,577
18×12	$20\frac{1}{2}$×48	14,003	$20\frac{1}{2}$×36	10,158

The reservoirs and brake cylinders, according to Table IV, are so proportioned that with 100 pounds brake-pipe pressure there is obtained for service applications from a 24-pound reduction an equalized pressure of 86 pounds in one brake cylinder with 8-inch piston travel, and for an emergency application an equalized pressure of 86 pounds in both brake cylinders with a piston travel of 9 inches.

TABLE V

BRAKE CYLINDERS AND RESERVOIRS FOR UC PASSENGER-CAR BRAKE EQUIPMENT

Single Brake-Cylinder Installation

Brake Cylinders	Auxiliary Reservoirs		Service Reservoirs		Emergency Reservoirs	
Size Inches	Size Inches	Volume Cu. In.	Size Inches	Volume Cu. In.	Size Inches	Volume Cu. In.
14×12	10×33	2,125	12×33	3,088	$18\frac{1}{2}$×42	10,014
16×12	10×33	2,125	14×33	4,476	$20\frac{1}{2}$×42	12,083
18×12	10×33	2,125	16×33	5,724	$22\frac{1}{2}$×48	16,661

The reservoirs and brake cylinders used with the UC equipment, Table V, are so proportioned that with 110 pounds brake-pipe pressure there is obtained for service applications from a 24-pound reduction a pressure of 60 pounds with an 8-inch piston travel and for an emergency application an equalized pressure of 100 pounds with a 9-inch piston travel.

AIR-PRESSURE CALCULATIONS

EXPLANATION OF PRESSURES

65. Purpose of Calculations.—The purpose of air-pressure calculations is to determine the pressure that is obtained in the brake cylinder when air is discharged into it from the auxiliary reservoir. Before problems involving air pressures can be attempted it is necessary to have a knowledge of atmospheric pressure, absolute pressure, gauge pressure, and of the manner in which air is affected when it is expanded and compressed.

66. Atmospheric Pressure.—By *atmospheric pressure* is meant the pressure that the atmosphere exerts by its weight. The atmosphere consists of air which completely surrounds the earth and extends upwards about 40 miles. Although a cubic foot of air has but little weight, a column of air with an area of 1 square inch and a height of 40 miles exerts a pressure of 14.7 pounds at sea level. In all ordinary calculations, the weight of the atmosphere, or the atmospheric pressure, is assumed to be 15 pounds per square inch.

67. Measuring Air Pressure.—An air gauge registers pressure, because the pressure in the interior of a tube is greater than the pressure of the atmosphere that surrounds the tube. An air gauge, therefore, cannot be used to measure the pressure of the atmosphere, because the air exerts the same pressure on all parts of the gauge. It is then necessary to remove the atmospheric pressure from a part of the apparatus that is used to determine the pressure, before the atmospheric pressure can be determined.

68. Method of Measuring Atmospheric Pressure. A simple method of determining the atmospheric pressure is illustrated in Fig. 20 (*a*) and (*b*). The glass tube shown is about 4 feet long and is closed at the upper end. The inside diameter of the tube is $1\frac{1}{8}$ inches and it therefore has an area of about 1 square inch.

The tube is filled with mercury, and the lower end is closed with the finger as shown in view (*a*). The tube is then inverted in the dish of mercury as shown in view (*b*) and the finger is removed. The weight of the atmosphere exerts a downward pressure on the mercury in the dish, and the pressure that is exerted on 1 square inch will now transmit an exactly equal upward pressure on the column of mercury in the tube, because the area of the column is also 1 square inch. The column of mercury will then descend until the weight of the mercury becomes the same as the upward pressure exerted against it by the weight of the air. The weight of the mercury which then remains in the tube must be equal to the pressure of the atmosphere per square inch. The mercury will be found to weigh about 15 pounds, which is, therefore, the pressure that the atmosphere exerts on 1 square inch on account of its weight.

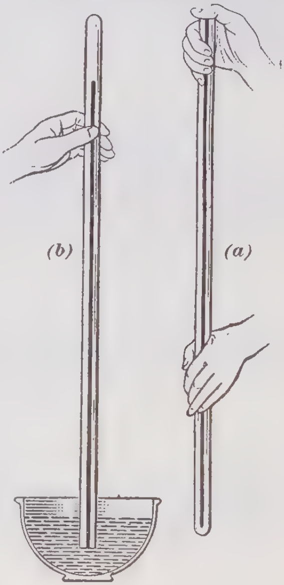


FIG. 20

69. Absolute Pressure and Gauge Pressure.—Absolute pressure is reckoned from the point of absolutely no pressure, and gauge pressure is reckoned from the point of atmospheric pressure, which is 15 pounds. The following explanation will serve to show the difference between absolute pressure and gauge pressure:

If a reservoir contains no air and it has attached to it a gauge

and also some device that will register atmospheric pressure and air is admitted to the reservoir, the device will show an increase in pressure, but the gauge hand will not move. When the reservoir is charged to atmospheric pressure the device will show 15 pounds pressure. If compressed air is now allowed to enter the reservoir, the gauge will immediately begin to register an increase of pressure, as well as the device that heretofore was registering atmospheric pressure. The device will then show 15 pounds more pressure than the gauge and this difference will be maintained as the pressure is increased. The pressure shown on the device is known as *absolute pressure*, and the pressure on the gauge as *gauge pressure*. To convert absolute pressure to gauge pressure, it is, therefore, merely necessary to subtract 15 pounds from the absolute pressure. To convert gauge pressure to absolute pressure, add 15 pounds to the gauge pressure. The gauge pressure may be considered as the pressure which tends to burst a reservoir. The first 15 pounds of absolute pressure exerts no pressure on the interior of a reservoir, because it is balanced by an equal atmospheric pressure on its exterior.

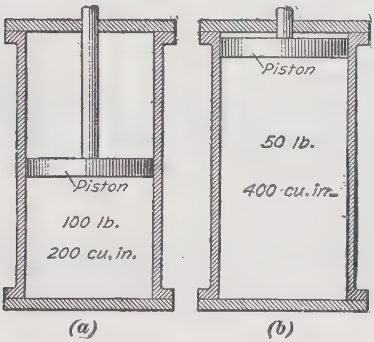


FIG. 21

VOLUME AND PRESSURE

70. Relation.—A certain definite relation exists between the volume of a certain quantity of air and the pressure to which the air is subjected, provided the temperature of the air remains the same. Reference will be made to Fig. 21 when explaining the relation between volume and pressure. The cylinders shown in Fig. 21, views (*a*) and (*b*), are of the same volume, and the pistons in them are assumed to work air-tight. The cylinder shown in view (*a*) contains air at an absolute pressure of 100 pounds to the square inch and the air is compressed into a space of 200 cubic inches.

Just how compressed air is affected when it is expanded will be shown first. If the force that acts downwards upon the piston in view (*a*) is gradually reduced, the pressure of the air will move the piston upwards, and view (*b*) shows that the pressure will decrease to 50 pounds to the square inch after the piston has moved, until the volume of the cylinder has become 400 cubic inches. Therefore, the pressure is decreased by one-half when the volume of the air is doubled.

How air is affected when it is compressed will next be shown. If the force which acts upon the piston in view (*b*) is increased until the air is compressed to a pressure of 100 pounds to the square inch, the air will occupy a volume of 200 cubic inches, as in view (*a*). The pressure is, therefore, doubled when the volume is decreased by one-half.

71. Rules Which Can Be Deduced.—It will be noted when the air is expanded, view (*a*), that the original pressure of the air multiplied by the volume of the air before it is expanded is equal, view (*b*), to the pressure of the air after it has been expanded, multiplied by the volume of the air after it has been expanded. Thus, $100 \times 200 = 50 \times 400$. It will also be noted when the air is compressed, view (*b*), that its pressure before compression multiplied by its volume before compression, is equal to the pressure after compression, multiplied by its volume after compression. Thus $50 \times 400 = 100 \times 200$. The following general rule can be deduced from the foregoing:

Rule I.—*The absolute pressure multiplied by the volume of the air before it is expanded or compressed is equal to the absolute pressure multiplied by the volume of the air after it is expanded or compressed.*

From this general rule three rules may be deduced and by means of these rules all problems which relate to brake-cylinder pressure may be solved. These rules as well as examples which will show how the rules are applied, will now be given.

Rule II.—*To find the absolute pressure after air is expanded, multiply the pressure before expansion by the volume before expansion and divide by the volume after expansion.*

EXAMPLE.—A reservoir with a volume of 540 cubic inches is charged with air at an absolute pressure of 150 pounds. The reservoir is connected to another reservoir which has a volume of 360 cubic inches. What is the absolute pressure and the gauge pressure when the pressure in both reservoirs has become equal?

SOLUTION.—The volume occupied by the air before expansion is 540 cubic inches, and the volume which the air occupies after expansion is $540 + 360 = 900$ cu. in. Therefore, from rule II, the absolute pressure after expansion is

$$\frac{150 \times 540}{900} = 90 \text{ lb. absolute pressure}$$

or $90 - 15 = 75$ lb. gauge pressure. Ans.

Rule III.—*To find the volume occupied by the air after it has been expanded, multiply the pressure before expansion by the volume before expansion, and divide by the pressure after expansion.*

EXAMPLE.—With the same reservoir and the same pressure as given in the example under rule II, find the volume occupied by the air after the pressure has been reduced to 1 pound absolute pressure.

SOLUTION.—From rule III, the volume occupied by the air is

$$\frac{150 \times 540}{1} = 81{,}000 \text{ cu. in.} \quad \text{Ans.}$$

It will be noted that the last example is solved by merely multiplying the pressure by the volume.

Rule IV.—*To find the pressure which results after air has been compressed, multiply the volume of the air before compression by the pressure before compression, and divide by the volume after compression.*

EXAMPLE.—What is the pressure when 500 cubic inches of air at 1 pound absolute pressure has been compressed into a space of 25 cubic inches?

SOLUTION.—From rule IV, the pressure is

$$\frac{500 \times 1}{25} = 20 \text{ lb., absolute pressure, or 5 pounds gauge pressure}$$

72. When Gauge Pressure May Be Used.—Gauge pressure may be used when the space into which the air expands already contains air at atmospheric pressure or at more than atmospheric pressure. Absolute pressure must always be used when air is expanded into a vacuum, which is a space which contains no air pressure. The space formed in the brake cylinder when the brake piston moves out contains practically no air pressure. Therefore, absolute pressure must be used when it is required to calculate the brake-cylinder pressure developed from a brake application.

APPLICATION OF AIR-PRESSURE RULES

BRAKE-CYLINDER PRESSURES

73. Calculating Pressure of Equalization.—The pressure obtained when the air in the auxiliary reservoir is allowed to enter the brake cylinder until the pressures are equal may be found by applying rule II of Art. **71**.

The solution of the following example shows how this rule is applied:

EXAMPLE.—The auxiliary reservoir of a standard 10-inch freight equipment is charged to a pressure of 70 pounds to the square inch. What is the pressure of equalization when the piston travel is 8 inches?

SOLUTION.—The volume of the auxiliary reservoir, and, therefore, of the air before expansion, is 2,440 cu. in. The absolute pressure before expansion is 85 lb. The volume of the brake cylinder is 675 cu. in. The volume of the air after expansion is equal to the combined volume of the auxiliary reservoir and the brake cylinder, or $2{,}440 + 675 = 3{,}115$ cu. in. From rule II, the gauge pressure of equalization is

$$\frac{85 \times 2{,}440}{3{,}115} - 15 = 51.5 \text{ pounds}$$

The calculated brake-pipe reduction necessary to cause equalization is, then, $70 - 51.5 = 18.5$ pounds and is not equal to 20 pounds, although the latter figure is the one that is always used.

74. Pressure Obtained From a Light Reduction. The brake-cylinder pressure resulting from less than a full-

service reduction can be determined from rules III and IV. The solution of the following problem shows the application of these two rules.

EXAMPLE.—The brake-pipe pressure, and, therefore, the auxiliary-reservoir pressure, is reduced 10 pounds in setting the brakes with a 10-inch freight equipment. What pressure will be developed in the brake cylinder with an 8-inch piston travel and a pressure of 70 pounds?

SOLUTION.—The first step is to find the volume of air, in cubic inches, which passes to the brake cylinder. The second step is to find the pressure this volume of air will develop in the brake cylinder.

In order to find the volume of air which passes to the brake cylinder, it is first necessary to find the volume which the air in the auxiliary reservoir would occupy if the air were expanded until the pressure becomes 1 pound per sq. in. From rule III, the volume of the air is $85 \times 2{,}440 = 207{,}400$ cu. in.

It is necessary next to find the volume that the air would occupy were it at a pressure of 75 pounds, which is 10 pounds less than 85 pounds. From the same rule, the volume of the air is $75 \times 2{,}440 = 183{,}000$ cu. in. The difference between 207,400 and 183,000, or 24,400 cu. in., must be the volume of air that enters the brake cylinder at an absolute pressure of 1 pound per square inch.

From rule IV, the pressure developed in the brake cylinder by this volume of air is equal to $\frac{24{,}400}{675} = 36$ lb. absolute pressure, or 21 lb. gauge pressure. Ans.

The air must be assumed to be expanded until the pressure is reduced to 1 pound per square inch absolute pressure, because volumes of air at different pressures cannot be added or subtracted. Therefore, it is necessary to reduce each volume of air to the same pressure before these operations can be performed.

75. It will be noted that the volume of the auxiliary reservoir multiplied by the reduction made will also give the volume of air in cubic inches at a pressure of 1 pound which passes to the brake cylinder. Thus, $2{,}440 \times 10 = 24{,}400$ cubic inches. Therefore, the quickest way to solve an example of this kind is to apply the following rule, which will give the absolute pressure in the brake cylinder.

Rule.—*To find the brake-cylinder pressure resulting from a certain brake-pipe reduction, multiply the volume of the auxiliary reservoir by the reduction and divide by the volume of the brake cylinder. Subtract 15 from the result to obtain the gauge pressure.*

If this rule is applied to the preceding example, the brake-cylinder pressure is $\frac{2{,}440 \times 10}{675} = 36$ pounds absolute pressure, or 21 pounds gauge pressure.

It may be asked why the rule just given could not be applied to problems involving the equalization of pressure. This rule will also apply to such problems provided the exact reduction necessary to produce equalization is known. For example, a reduction of 18.5 pounds will equalize the auxiliary-reservoir and brake-cylinder pressures, if the pressure in the auxiliary reservoir is 70 pounds. Therefore, the brake-cylinder pressure developed is

$$\frac{2{,}440 \times 18.5}{675} = 66.8 \text{ pounds absolute pressure}$$

or 51.8 lb. gauge pressure. This corresponds closely to the answer obtained in Art. **73**.

MISCELLANEOUS

76. High or Low Brake-Pipe Pressure Gives Same Brake-Cylinder Pressure.—The foregoing rule makes no mention of the pressure which is in the auxiliary reservoir and only takes account of the volume of the auxiliary reservoir and the reduction. Therefore, within certain limits, the same pressure is obtained in the brake cylinder when the pressure in the brake pipe and the auxiliary reservoir is low as when the pressure in these parts is high. For example, a reduction in brake-pipe pressure of 10 pounds will give the same pressure in the brake cylinder whether the brake system is charged to 70 pounds or to 110 pounds.

The reason is as follows: If the pressure in a reservoir is increased by compressing into it at intervals the same volume of air, it will be found that the addition of each volume of air

increases the pressure in the reservoir an equal amount. If the pressure in the reservoir is increased 1 pound by each volume of air that is compressed into it, and if the pressure is 50 pounds to start with, the compression of 1 volume of air increases the pressure to 51 pounds, the next to 52, and so on. The fact that the pressure in the reservoir is being increased does not affect the amount that the compression of the air increases the pressure. The action of the air in always increasing the pressure the same amount may be compared to placing additional weights on a scale. Regardless of the number of weights on the scale, the addition of an ounce or a pound increases the same amount the weight which the scale registers.

As the admission of a certain volume of air raises different pressures an equal amount, it follows when different pressures are reduced an equal amount, that the same volume of air escapes and therefore develops the same pressure.

The advantage of a high brake-pipe pressure is that the pressure of equalization is higher than when the pressure is lower. More full-service applications can also be made before it becomes necessary to recharge the brake system when the brake-pipe pressure is high than when it is low.

77. The following example shows that the pressure is increased the same amount when the same volume of air is added to different pressures. There are, it is assumed, three reservoirs with a volume of 100 cubic inches, and each is charged to a pressure of 200, 300, and 400 pounds pressure per square inch. It will be further assumed that 20 cubic inches of air at atmospheric pressure is the volume which is to be compressed into each reservoir. The amount by which this volume of air will increase the pressure in each reservoir is found as follows:

From rule III, the volume occupied by the air in the reservoirs if the air were expanded until the pressure becomes 1 pound per square inch, is equal to the pressure multiplied by the volume. The volume of the air would be equal to 20,000, 30,000, and 40,000 cubic inches when the pressure is 1 pound per square inch. The volume occupied by the air which is to be compressed into the reservoir when the pressure is 1 pound

per square inch is equal to $20 \times 15 = 300$ cubic inches. All the air pressures are now reduced to the same pressure, and therefore 300 cubic inches can be added to the volume that is occupied by the air in the reservoirs. The volume of air that is to be compressed into the respective reservoirs is then equal to 20,300, 30,300, and 40,300 cubic inches.

From rule IV, the pressure which will result may be found by dividing the volume of the air at a pressure of 1 pound per square inch by the volume of the reservoir into which each volume of air is compressed. The result obtained is 203, 303, and 403 pounds, or the compression of 20 cubic inches of air into the reservoirs has raised the pressure 3 pounds in each.

78. Brake-Cylinder Pressure With Retaining Valve. The following example shows how to calculate the pressure at which the air in the auxiliary reservoir will equalize with the brake cylinder when the retaining valve is in use:

Example.—What will be the pressure of equalization with 15 pounds retained in the brake cylinder of a 10-inch freight equipment, the auxiliary reservoir of which is changed to 70 pounds.

Solution.—From rule III, the air in the brake cylinder occupies a volume of $15 \times 675 = 10{,}125$ cu. in., when the pressure is reduced to 1 pound per square inch. Likewise, the air in the auxiliary reservoir will occupy a volume of $2{,}440 \times 70 = 170{,}800$ cu. in. The total volume of air to be compressed into the combined volumes of the auxiliary reservoir and the brake cylinder is $170{,}800 + 10{,}125 = 180{,}925$ cu. in.

From rule IV, the brake-cylinder pressure is $\frac{180{,}925}{675 + 2{,}440} = 58$ lb.

AIR-SIGNAL SYSTEM

TRAIN AIR-SIGNALING SYSTEM

GENERAL ARRANGEMENT OF APPARATUS

1. The general arrangement of the train **air-signaling apparatus** on an engine, tender, and passenger car is shown in Figs. 1 and 2. This system has gradually taken the place of the old bell-cord-and-gong method of signaling on passenger trains, on account of the ease and certainty with which signals can be transmitted to the engineer from any part of the train.

The engine, tender, and each of the cars are piped with a $\frac{3}{4}$-inch pipe, which is connected between cars by means of hose, so that when all the hose is coupled, the signal-pipe line extends throughout the entire train.

A *car discharge valve*, Fig. 1, is provided on each car. This is usually located outside the car above the door, as shown in the figure, and is piped to the train signal pipe. Sometimes, however, it is placed inside the car above the door, to guard against the valve being clogged in winter. The former position is preferable, however, as the chances of clogging are small, and the annoyance caused by the sharp sound of discharging air every time the valve is opened to make signals is avoided.

A signal cord is attached to the lever of the discharge valve, and one end extends across the platform and is fastened in a suitable manner to the hood, while the other

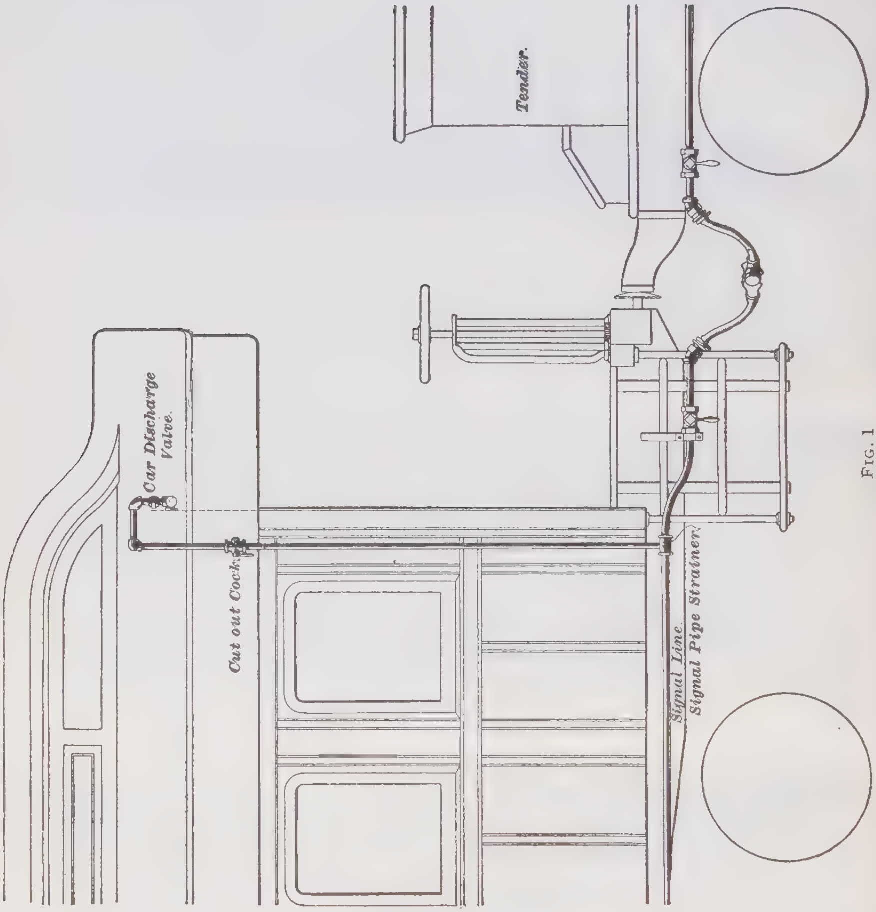

Tender.
Car Discharge
Valve.
Cut out Cock
Signal Line.
Signal Pipe Strainer.

FIG. 1

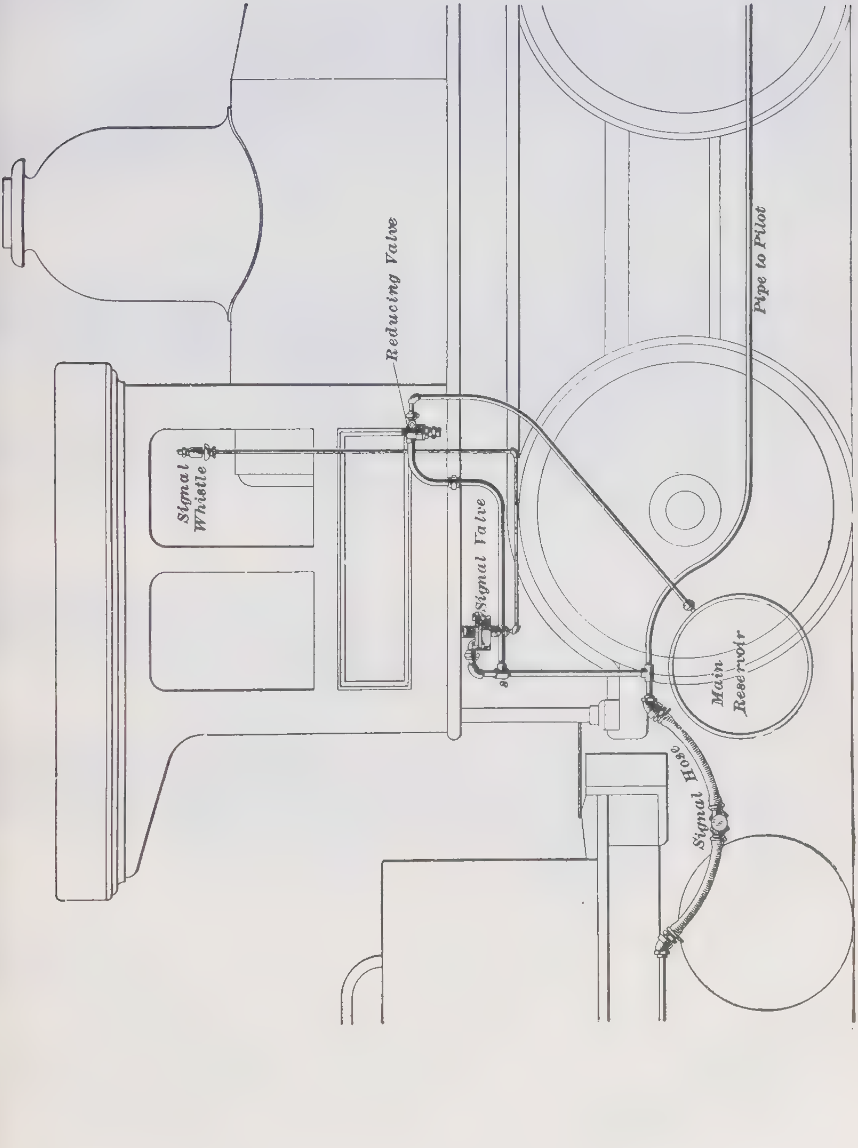

Reducing Valve
Signal Whistle
Signal Valve
Pipe to Pilot
Main Reservoir
Signal Hose

Fig. 2

end extends through the car and is fastened to the hood on the other end of the car. This cord enables the discharge valve to be operated from any part of the car.

The air-signal apparatus on the engine, Fig. 2, consists of the *signal valve*, *signal whistle*, and *pressure-reducing valve*. A $\frac{3}{8}$-inch pipe leads from the main reservoir to an air strainer, then to the reducing valve, and thence leads to, and connects with, the **T**-fitting *s* in the signal pipe. Air from the main reservoir can thus pass through the pressure-reducing valve and thence into the signal pipe and signal valve, but the pressure of the air will be reduced to the pressure the reducing valve is set for. A pressure of 40 pounds is maintained in the signal system, and the duty of the reducing valve is to diminish the pressure from 90 pounds (main-reservoir pressure) to the required pressure for use in the signal system.

The **signal whistle,** Fig. 3 (a small whistle located in the cab, as close to the engineer as practicable), is piped to the signal valve, and it is the operation of the latter that causes the whistle to blow.

When the conductor wishes to transmit a signal to the engineer, he gives the signal cord in one of the cars a pull. This opens the discharge valve on that car and allows some of the air in the main signal pipe to escape to the atmosphere, thus reducing the signal-pipe pressure. The reduction in pressure operates the signal valve on the engine, which consequently discharges a small quantity of air through the signal whistle in the cab, thus causing it to sound a short blast. Each time the cord is pulled, the signal whistle gives a blast.

The bowl *1* forms the base of the whistle and connects with the whistle pipe at *X*. The passage *a'* and port *a* form a passage from the whistle pipe into chamber *A*. The disk *2* deflects the escaping air and makes it strike the edge of the bell *3* of the whistle. The tone of the whistle depends on the depth of chamber *B*. The check-nut *4* and cap nut *5* act as locknuts to lock the bell of the whistle in position after it has been adjusted.

An imperfect adjustment of the whistle bell, or its bowl being filled with dirt, will either cause the whistle to work badly or prevent its working at all. No set rule can be given for the adjustment of the whistle, but it must be so adjusted as to give the best sound. To adjust the whistle, slack off nut *5* and turn the whistle bell up or down until the

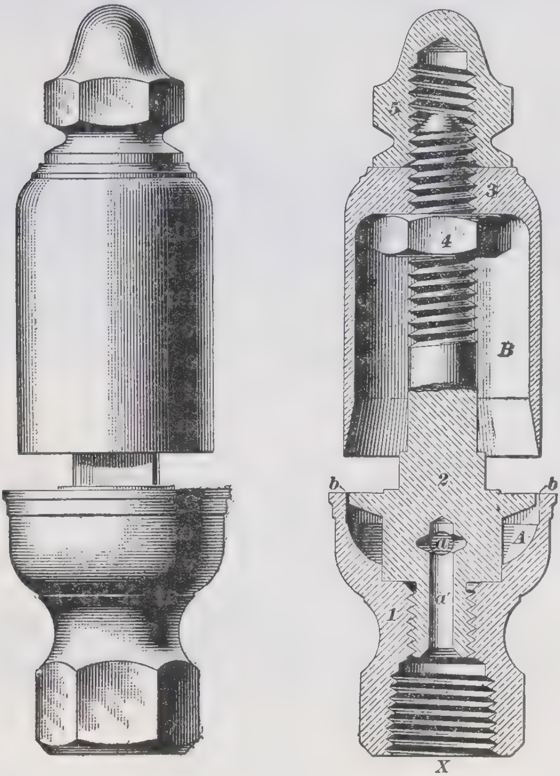


Fig. 3

desired result is obtained. A jam nut *4* on the whistle stem is an aid to the locknut in holding the whistle bell in any desired position. Care should be taken not to locate the whistle near one of the cab windows where a current of air will be liable to blow across it, as a strong current of air blowing across the whistle will render it inoperative.

DESCRIPTION OF APPARATUS

REDUCING VALVE (OLD STYLE)

2. Although this style of **reducing valve, Fig. 4,** has been superseded to a great extent by the improved valve, there are still a sufficient number in use to warrant a description of them being given here.

The main-reservoir connection is made at *X*, while a pipe leads from *Y* to the signal pipe. *4* is the supply valve that regulates the admission of air to the signal system; it is operated by the stem of the reducing-valve piston *8* and by the supply-valve spring *10*. *7* is the rubber diaphragm; *6*, the diaphragm ring; and *9*, the regulating spring. In this style of valve, the spring *9* was made strong enough to just resist a pressure of 25 pounds per square inch in chamber *B*. It is now the practice, however, to use a spring that requires a pressure of 40 pounds per square inch to compress it. The outlets *e*, *e* in the cap *3* prevent air (due to leakage) from accumulating back of the piston and piston stem and rendering the valve inoperative.

3. Operation of Valve.—The operation of this valve is as follows: The spring *9*, acting on the piston *8*, causes the stem of the piston to hold supply valve *4* from its seat, so that main-reservoir air entering at *X* is free to pass through the passages *2*, *2*, past valve *4* and into chamber *B*, and thence through the outlet *Y* to the signal pipe. This increases the pressure in the signal pipe and chamber *B* until it reaches 40 pounds per square inch, when the diaphragm 7 and piston *8* are forced upwards against the action of the spring *9*. The supply-valve spring *10* then forces the supply valve to its seat, and prevents the further passage of air from the main reservoir to the signal pipe. As long as the pressure in chamber *B* remains at 40 pounds, spring *9* will be compressed and the supply valve will remain closed. Any reduction of pressure in chamber *B*, however, will cause the regulating spring to force the diaphragm 7 and piston *8*

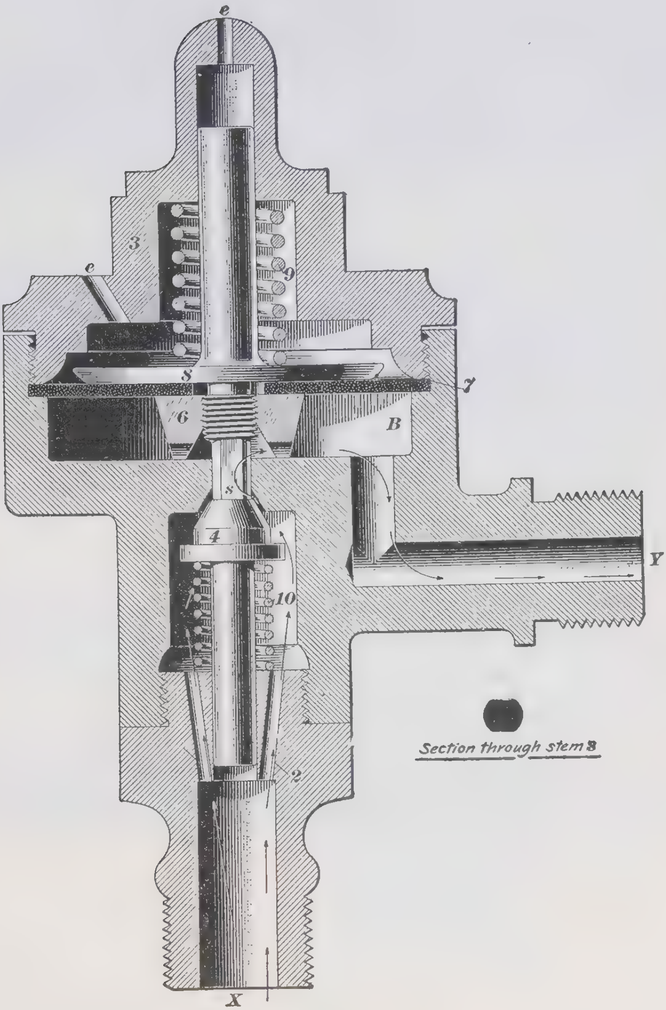


FIG. 4

downwards, thus forcing the supply valve from its seat and allowing sufficient air to pass to the signal pipe to raise its pressure again to 40 pounds, when the supply valve will close. The old-style valve has no regulating nut by means of which the tension of the regulating spring can be adjusted to alter signal-pipe pressure. If it is necessary to increase the signal-pipe pressure, the regulating spring *9* will have to be replaced by one that is stiffer. The weak part of this valve was the diaphragm *7*, which deteriorated rapidly, allowing air to leak through it to the atmosphere.

REDUCING VALVE (IMPROVED)

4. The **improved reducing valve** is shown in Fig. 5; *16* is a choke plug that restricts the flow of air through the valve so that the reducing valve cannot supply air to the signal pipe faster than the car discharge valve can reduce the pressure; *2* is a plug cock that, in the position here shown, is allowing air to enter the reducing valve, but, when turned at right angles to its present position, cuts the valve out of service; *3* is the lower cap; *4*, the supply valve; *5*, the supply-valve cap nut; *6*, the supply-valve spring; *7*, the reducing-valve piston; *8*, a rubber diaphragm consisting of two pieces of rubber; *9*, the regulating spring; *10*, the diaphragm ring; *11*, the piston packing ring (which, together with the diaphragm, serves to prevent leakage of air past piston *7*); *14*, the regulating nut by means of which the tension of the spring *9* is adjusted; and *15*, the check-nut. The passage *e* is to allow any air leaking past the piston *7* to escape to the atmosphere.

5. Operation of Valve.—The tension of the regulating spring *9* is adjusted to just withstand a pressure of 40 pounds per square inch in chamber *B*. When the pressure is less than this amount, the spring *9* forces piston *7* upwards and the piston stem unseats the supply valve *4*. Main-reservoir air (entering at *X*) is then free to pass through the plug cock *2*, supply valve *4*, and thence out through *Y* to the signal pipe. As soon as the pressure in the signal pipe and

chamber *B* reaches 40 pounds, piston *7* is forced downwards and the spring *6* forces the supply valve to its seat, closing communication between the main reservoir and the signal pipe. Any reduction in signal-pipe pressure will allow the

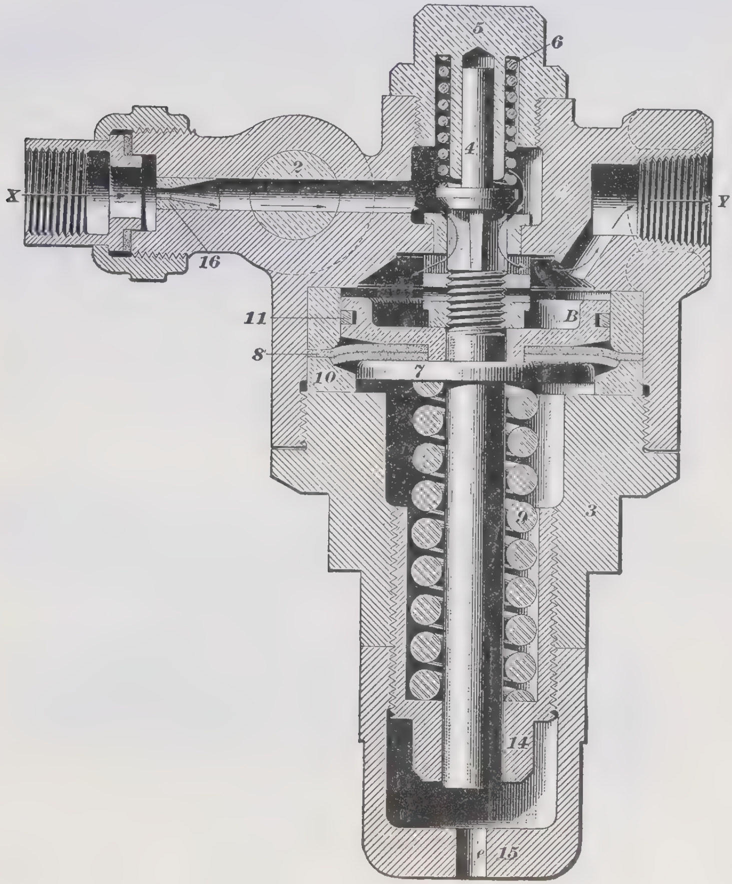


Fig. 5

spring *9* to force piston *7* upwards, thus opening the supply valve again. The valve then remains open until the signal-pipe pressure is again raised to 40 pounds, when it closes.

The reducing valve should be placed in the cab, in some moderately warm place, if possible, to prevent its freezing in cold weather.

With the improved valve, the signal-pipe pressure may be increased by screwing up the regulating nut *14*, or decreased by unscrewing this nut.

CAR DISCHARGE VALVE

6. A sectional view of the **car discharge valve** is shown in Fig. 6, in which *3* is the discharge valve and *4* the discharge-valve spring that holds this valve up against its seat. *5* is the lever, or handle, to which the signal cord is attached, while *6*, *6* are stop-pins. There is a union connection at *a* to which the branch pipe from the signal pipe is connected, while the exhaust port *b* leads to the atmosphere.

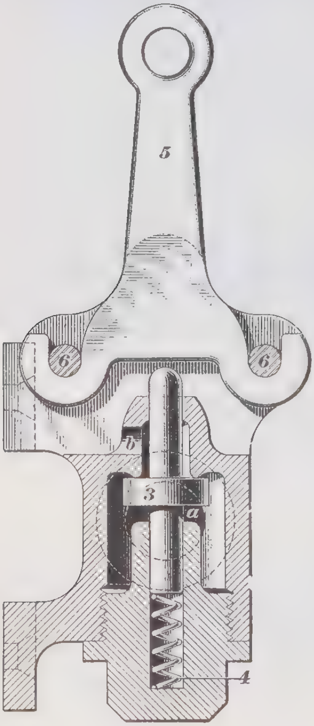


FIG. 6

7. Operation of Valve. When the signal cord on either side of the discharge valve is pulled, the lever *5* is caused to strike the stem of the discharge valve *3* and force the valve from its seat. Air from the signal pipe then passes through the branch pipes and out to the atmosphere through the union connection *a* and the port *b*, causing a reduction in signal-pipe pressure. As soon as the signal cord is released, the spring *4* forces the discharge valve to its seat again and stops the discharge of air from the signal pipe.

Referring to Fig. 1, it will be seen that the branch pipe to the discharge valve is supplied with a strainer (where it

connects with the main signal pipe) and a cut-out cock, the former to prevent dirt from reaching the discharge valve, and the latter to enable the discharge valve to be cut out in case it is disabled. The handle of the cut-out cock stands parallel with the pipe when the discharge valve is cut out, and at right angles to it when cut in. Also, the cut-out cocks in the signal pipe on either side of the signal hose are closed when the handles stand parallel with the pipe, and open when at right angles to it. The couplings in the signal hose are of a different size from those in the air-brake hose; thus, the signal hose and brake hose cannot be coupled by mistake.

THE SIGNAL VALVE

8. **The signal valve,** Fig. 7, is located under the cab, either on the engineer's or the fireman's side. The signal

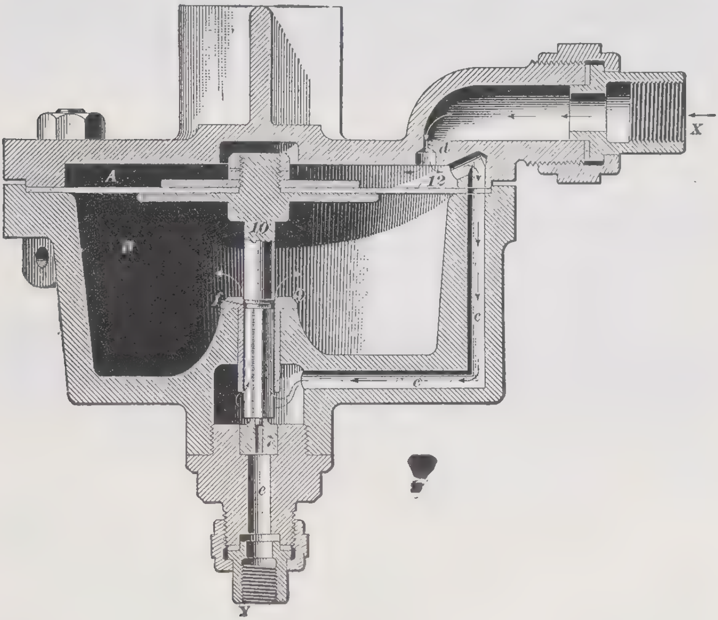


Fig. 7

pipe connects at *X*, while a pipe leads from *Y* to the whistle. The valve body is divided into two chambers *A* and *B* by

the rubber diaphragm *12*, which is attached to and operates the diaphragm stem *10*. This stem extends through the bushing *9*, and its end forms a valve (with seat in bushing *7*) that controls the passage *e* leading to the whistle. A small portion of the stem *10* fits the bushing *9* snugly; below this a groove *f* is cut around the stem. Below groove *f* the stem is milled to a cross-section like that shown at *x*. Port *d* is made small so as to restrict the flow of air into and out of chamber *A* sufficiently to cause chamber *A* pressure to charge at about the same rate for different lengths of train. This is necessary in order to make the signal valve operate the same on both short and long trains. A given reduction in signal-pipe pressure can be made much more quickly on a short train than on a long one, so that if port *d* were not restricted, chamber *A* pressure would change much faster on a short train than on a long one. With port *d* of its present size, however, chamber *A* pressure charges at nearly the same rate for long and short trains, so that the signal valve operates about the same on trains of different length.

9. Operation of Valve.—When the signal pipe is being charged, air enters the signal valve at *X*, and, passing through the small port *d*, charges chamber *A*. It also passes through the passage *c c* and feeds up slowly past the stem *10* into chamber *B*, charging this to the same pressure as chamber *A*. The pressures in chambers *A* and *B* and the signal pipe are equal when the pipe is fully charged.

When the signal cord is pulled and a reduction is made in the signal pipe, it causes a reduction of pressure in the signal valve also; but, since the stem *10* makes a rather snug fit, the pressure in chamber *A* above the diaphragm reduces faster than the pressure in chamber *B*; consequently, the diaphragm is forced upwards, and raises the stem *10*, thus opening the port in valve seat *7*. The stem *10* is lifted until the groove *f* is above the bushing *9*, when the air in chamber *B* escapes quickly through the groove *f*, the milled spaces in the stem *10*, and the passage *e*, out to *Y* and the whistle, causing the latter to give a blast. Air also escapes

from chamber *A* to the whistle, through the passages *c c* and *e*, but is restricted in its passage from the train signal pipe into *A* by the small port *d*.

The same reduction of pressure that operates the signal valve also opens the reducing valve, allowing air from main reservoir to flow into, and raise the pressure in, the signal pipe. This increase of pressure, following the closing of the car discharge valve, and immediately after the reduction in signal valve, increases the pressure in chamber *A* faster than in chamber *B*, thus forcing the diaphragm downwards, closing the valve leading to passage *e*, and stopping the blast of the whistle.

SIGNALING

10. In **transmitting signals** by means of the air-signaling system, certain precautions must be observed in order to obtain good results. For each blast of the whistle, the car discharge valve should be held wide open just long enough to reduce the pressure in the signal pipe clear up to the signal valve on the engine, when it should be closed. It should then be allowed to remain closed until the pressure has equalized throughout the system, before it is again opened to transmit another signal. If the discharge valve is opened a second and, possibly, a third time before the whistle has ceased to blow due to the first reduction, the whistle will give one long blast instead of two or three short ones, as intended. If it is opened a second time before the pressure has fully equalized in the signal pipe, the whistle will give a blast after each discharge, but the last blast will be weak on account of the pressure being less than 40 pounds. If the discharge valve is not held wide open when giving a signal, the reducing valve may feed air into the signal pipe as fast as it escapes from the car discharge valve and the whistle will not give a blast.

In transmitting signals, the best results will be obtained if the car discharge valve is allowed to remain closed from 2 to 3 seconds between blasts, depending on the length of the

train; that is, for each blast, pull the signal cord straight downwards and hold the discharge valve wide open for 1 second; then allow from 2 to 3 seconds for the pressure to equalize throughout the signal pipe before opening it for another blast. As it takes a longer or heavier discharge from the signal pipe from the rear car of a long train than from the front car, it will take longer for the signal pipe to equalize and a longer interval between the blasts is necessary to get perfect signals.

DEFECTS IN THE SIGNALING SYSTEM

11. Although the air-signaling system has only comparatively few parts, good judgment is required to locate defects that cause incorrect signals to be given. Another thing to consider is that it is not so much the amount of the reduction as the rapidity with which it is made, that causes the whistle to blow.

SIGNAL PIPE FAILS TO CHARGE

12. If no air passes into the signal pipe, first see whether the cocks on each side of the hose between the tender and train have been opened. If so, plug cock *2* may be closed, or the opening in plug *16* of the reducing valve, Fig. 5, may be stopped up with oil and dirt, or the lining in the hose may be loose and blocking the passage; or, if the weather is cold, the signal pipe on the engine or tender may be stopped up with ice, or the reducing valve may be frozen up.

NO EXHAUST FROM DISCHARGE VALVE

13. If no exhaust occurs at the discharge valve when the signal cord is pulled, the signal pipe being properly charged, the trouble may be due to the cut-out cock, Fig. 1 (usually placed in the saloon), being turned so as to cut out the discharge valve, to a loose seat in discharge valve *3*, to a stopped-up strainer in the signal pipe **T**, or to a collapsed hose lining.

WHISTLE FAILS TO BLOW

14. If an exhaust occurs at the discharge valve when the signal cord is pulled, but the signal whistle fails to give a blast, the trouble may be due to the strainer in the **T**, where the branch pipe connects with the signal pipe, being stopped up (see Fig. 1). In this case, the exhaust may sound all right, since there is considerable air in the branch pipe between the strainer and the discharge valve, but the air in the main pipe cannot get past the strainer fast enough to make a sufficiently quick reduction to operate the signal valve. If the trouble is not in the strainer, it may be that: port *d* of the signal valve is stopped up, in which case no air can enter the valve to charge it; stem *10* of signal valve has worn sufficiently loose in bushing *9* to allow pressure in chamber *B* to reduce about as fast as that in chamber *A*; the signal-valve diaphragm is bagged or, possibly, cracked; the bell of the signal whistle is imperfectly adjusted or its bowl is full of dirt; the whistle is so situated that wind blowing across the bowl prevents it from sounding; or it may be dirt in port of bushing *7*.

If poor rubber is used in the diaphragm, or if oil gets on it, the rubber will, in time, stretch and bag. In that event, when a signal-pipe reduction is made, the diaphragm will respond to it without raising the stem *10* from its seat in *7*, and no blast will result. An overheated air pump also tends greatly to heat the rubber and buckle or distort the diaphragm. In some cases, the diaphragm cracks, causing chambers *A* and *B* to become directly connected, in which case it is impossible to produce the difference in pressure on the two faces of the diaphragm necessary to operate the signal valve.

WHISTLE GIVES ONE LONG BLAST

15. If, in transmitting a signal, the whistle simply gives one long blast, it may be due either to the reductions being made too close together, or to the diaphragm stem *10* of the signal valve working stiffly in the bushing *9*, in which event

the passage at *e* would remain open until sufficient difference of pressure existed in chambers *A* and *B* to force stem *10* to its seat. Also, a sluggish signal reducing valve, by not opening promptly, will make the blast longer than it should be.

WHISTLE BLOWS WHEN BRAKES ARE RELEASED

16. If the whistle blows every time the brakes are released, it indicates that there is direct connection between the main reservoir and signal pipe, and that the latter is charged to main-reservoir pressure. This may be due to valve *4* of the reducing valve being held open by dirt on its seat, to too much tension in spring *9*, or to cap nut *5* being screwed up so tight that it is twisted out of shape and will not allow supply valve *4* to seat properly; or (in the old-style reducing valve, Fig. 4) to spring *10* being broken or too short, so that it does not force valve *4* to its seat.

The reason why the whistle blows when the brakes are released is as follows: As there is a direct opening between the signal pipe and the main reservoir, air will flow from the former to the latter every time the main-reservoir pressure is reduced in releasing the brakes. This causes a reduction of signal-pipe pressure right at the signal valve. This, if the opening through the reducing valve is large enough and the main-reservoir pressure is reduced sufficiently fast, will operate the signal valve and cause the whistle to give a blast. If the opening through the reducing valve is small, the whistle may not sound if the signal pipe is long, whereas it may do so on a short train or on a long engine.

Main-reservoir pressure in the signal pipe can be detected from the train by a stronger discharge of air from the discharge valve when the signal cord is pulled; on the engine it will be indicated by the signal whistle screeching, due to the fact that the bell of the whistle is adjusted for 40 pounds pressure and not for 90.

If the signal-pipe pressure is much less than 40 pounds, the discharge will be weaker than it should be when the cord is pulled, and the whistle will give a weaker blast than it should.

WHISTLE GIVES WEAK BLAST

17. Sometimes the whistle only gives a weak blast when the cord is pulled. This may be due to the regulating spring of the reducing valve being too weak, so that there is less than 40 pounds in the signal pipe; the whistle may be full of dirt or be improperly adjusted; or the passage through the bushing *7* in the signal valve, Fig. 7, may be partly stopped up with oil and dirt.

SIGNAL VALVE LEAKS

18. If, in the signal valve, Fig. 7, the valve formed by the end of the stem *10* leaks or is held from its seat on bushing *7* by dirt, there will be a constant blow at the whistle.

LEAKY CAR DISCHARGE VALVE

19. A leaky car discharge valve, due either to dirt on the seat of the valve or to a defective valve seat, is a common source of trouble. If dirt on the valve seat is the cause of the leak, opening and closing the valve will blow the dirt off. As a rule this leak will be supplied by the reducing valve without causing a blast of the whistle. If the leak is such as to sound the whistle, and the valve cannot be replaced or repaired on the road, cut the valve out of service by closing the cut-out cock on the signal-pipe cross-over pipe.

STEM *10* TOO TIGHT IN BUSHING *9*

20. The accuracy with which signals can be transmitted depends, to a considerable extent, on the fit of the stem *10* in the bushing *9*. If it makes too tight a fit, the whistle will give one long blast instead of the usual short ones, as already explained. Also, signal-pipe leakage is liable to operate the signal valve and cause the whistle to sound a blast, and the signal valve will not respond to a short, light reduction.

WHISTLE BLOWS ON SHORT TRAIN BUT NOT FROM REAR END OF LONG TRAIN

21. If the fit of the stem is too loose or the diaphragm is baggy, the signal valve may not be affected by leaks; neither will it respond to a light, quick reduction in signal-pipe pressure. Also, when the train is short, the signal valve will respond to a reduction made on any of the cars in the train; but on a long train, the volume of air in the signal pipe is so much larger that a reduction through the car discharge valve from the rear cars may not produce a reduction sufficiently rapid at the signal valve to operate that valve, and the whistle will not sound.

WHISTLE GIVES TWO OR MORE BLASTS INSTEAD OF ONE

22. If the stem *10* of the signal valve fits too loosely in bushing *9* and the train is short, the whistle, when the cord is pulled, is liable to give two or three blasts instead of one. This is brought about as follows: As the cord is pulled, a reduction is made in the signal valve above the diaphragm, which causes the diaphragm to be raised, thus allowing air to escape from chamber *B* to the whistle, causing it to give a blast. The pressures in chambers *A* and *B* immediately equalize, causing the stem valve to close and stop the whistle. Then, as the reduction in the signal pipe continues, another difference in pressure forms between chambers *A* and *B*, causing the stem valve to be again opened and sounding another blast. In this way, two or more blasts may occur when but one reduction is made. When the stem fits properly, the pressure in the chamber above the diaphragm increases much faster than that in the chamber below it; hence, the diaphragm is held down and a second blast does not occur. In case the signal whistle gives two blasts when the cord is pulled, it can be remedied by lowering the stem *10* in the bushing *9*. The length of fit of the stem in its bushing should never be less than $\frac{1}{32}$ inch, nor more than $\frac{1}{16}$ inch, measuring from the top of groove *f* to the top of bushing *9*.

WHISTLE BLOWS WITHOUT APPARENT CAUSE

23. This is caused by a leak in the signal pipe, and occurs while the engine is running along. The leak reduces the pressure in chamber *A* of the signal valve just a little below that in chamber *B*, so that a very slight jar of the engine will sometimes cause the diaphragm to rise and open stem valve *10*, thus causing a blast of the whistle. This trouble is aggravated if the supply valve of the reducing valve rusts a little or sticks, caused by its freezing or otherwise.

DOUBLE-HEADING

24. In double-heading, the whistles on both engines should sound each time a signal-pipe reduction is made. If they do not, close the cut-out cock in the reducing valve on the second engine: this reducing valve feeding into the signal valves prevents the signal-pipe reduction passing to the head engine to operate the signal valve.

TERMINAL TEST OF AIR-SIGNAL APPARATUS

25. In making up a train, the air-signal hose should be connected up at the same time the air-brake hose is, and all the signal-pipe cocks opened except the rear cock on the last car of the train; this should be closed, and the signal hose hung up properly. While looking over the train for leaks, the signal hose and couplings and also the car discharge valves should be inspected to see if they are in good condition. If a discharge valve is found to be leaking, jerk it open a few times; if this does not remedy the leak, the valve needs a new gasket. If a discharge valve is found defective while on the road, it should be cut out by closing the cut-out cock in the branch pipe; the conductor should be notified and report the same for repairs at the end of the run. In testing the signal system, signals should be transmitted from the rear car, from a car in the center, and also from the car next to the engine.

To test the reducing valve from the brake valve, start the pump with the brake valve on lap and the tender angle cock open. When the pressure reaches 50 pounds, stop the pump and at regular intervals move the brake valve to running position for a few seconds and back to lap. This will reduce the reservoir pressure gradually; when it reaches a pressure slightly below that at which the reducing valve operates, air will pass out of the signal pipe into the reservoir, causing a signal-pipe reduction that makes the whistle blow.

TESTING DEVICE

26. A device for testing the signal apparatus consists of a signal-hose coupler fitted with an air gauge and a small petcock having a $\frac{1}{8}$-inch hole in it. When this device is coupled to the signal hose, and the signal-pipe stop-cock is opened, the signal-pipe pressure will be indicated by the air gauge, while, by means of the petcock, a reduction of any amount or duration may be made in the signal-pipe pressure.

27. **Using the Device.**—The **testing device** may be used to determine the condition of the air-signal reducing valve as follows: First open the cut-out cock and then connect the device into the signal pipe and charge the latter to standard pressure. Opening the cut-out cock first reduces signal-pipe pressure and thus protects the gauge. Also, the gauge will indicate the condition of the reducing valve by showing the rate of increase of signal-pipe pressure. Next open the petcock wide, make a 10-pound reduction, and note the time required to raise the pressure to standard again. If the pressure rises slowly and the reducing valve is of the improved type, the passage through the valve is probably reduced by gum and dirt, and the valve should be thoroughly cleaned. If the reducing valve is of the old style, it may be that the supply valve does not open sufficiently to admit of its feeding faster, and the valve should be taken down and repaired.

To test the signal valve, make a slow, gradual reduction of about the same magnitude as the leaks in the signal pipe would amount to; then gradually increase the rate of discharge until the signal whistle sounds. If the whistle blows when a slow gradual reduction is being made, it indicates that the stem *10* is not too loose a fit in the bushing *9*, and that the pressure on the under side of the diaphragm cannot escape as the pressure above is reduced. The consequence is that the pressure in chamber *B* raises the diaphragm as soon as a sufficient difference of pressure is established between the chambers on either side of the diaphragm, and air discharges into the whistle, causing it to sound. If the whistle does not blow when a slow, gradual reduction is made, the indications are that the stem *10* fits too loosely in the bushing *9* or the diaphragm is bagged. If the stem is too tight in the bushing *9*, the signal valve will not close promptly and the blast will be drawn out longer than it should.

This device should be used as frequently as convenient so as to keep the apparatus in good condition. The test should be made before the engine leaves the roundhouse so that all necessary repairs can be made before the engine is coupled to the train.

P C PASSENGER BRAKE EQUIPMENT

PURPOSE OF THE BRAKE

1. Reason for Development.—The **schedule P C equipment** was designed especially for passenger-train service to control passenger cars weighing 130,000 or more pounds. Passenger brake cylinders had been increased from time to time as the increased weight of the cars demanded, until the 18-inch cylinder finally came into use. This brake cylinder provided for cars of maximum weight up to 127,000 pounds. When cars of 150,000 or more pounds were under construction, it became necessary either to use a 20-inch brake cylinder or to redesign the brake rigging so as to provide for a suitable brake for this service. A very serious objection to the use of a 20-inch cylinder was the time necessary to apply the brake to its full capacity. At 80 miles per hour, the speed is 116 feet per second; and at 60 miles per hour it is 88 feet per second. A couple of seconds, therefore, meant a couple of hundred feet passed over before the brake would begin to be effective, thus greatly lengthening the distance in which a stop could be made. Another objection to the use of a 20-inch cylinder was that on account of leakage the stop would be lengthened still more, it being impossible to obtain packing leathers large enough and of sufficient uniformity to prevent excessive leakage. Then, too, the question of clearance space for the cylinders had to be considered, and it was found that the piston rods, drivers, etc. would be so large and heavy that they would take up too great a percentage of the power developed. The

increased weight of the cars naturally brought increased length of trains, and the larger cylinders and greater train length meant that a much greater volume of air had to be handled through the brake pipe. This would make the action of the brake on a train of cars with 20-inch cylinders so slow that it would be impossible to control the heavy cars with nearly the same effectiveness as is obtained with the brake used on lighter cars.

2. Train Energy to Be Controlled.—Table I has been compiled in order to give a clear idea of the tremendous amount of energy that the brake of a modern heavy passenger train has to destroy in stopping the train.

TABLE I

ENERGY OF TRAIN AT DIFFERENT SPEEDS

Speed Miles per Hour	Velocity Head Feet	Energy in Foot-Pounds per 1,000 Pounds of Weight	Total Energy, in Foot-Pounds, of Train Weighing 1,650,000 Pounds
10	3.55	3,550	5,857,500
20	14.20	14,200	23,430,000
30	31.95	31,950	52,717,500
40	56.80	56,800	93,720,000
50	88.75	88,750	146,437,500
60	127.80	127,800	210,870,000
70	173.95	173,950	287,017,500

The velocity head multiplied by the weight of the train in pounds will give the energy in foot-pounds for that speed. The third column of the table gives the energy of each 1,000 pounds of train at the different speeds given in the first column. The rate of change of the energy of 1,000 pounds of train with the increase in speed is indicated in the curve shown in Fig. 1, which is plotted from the values given in the third column of Table I. Both the table and the curve show that the energy of each 1,000 pounds of train is four times as great at 20 miles

per hour as at 10 miles per hour; nine times as great at 30 miles as at 10 miles; sixteen times as great at 40 miles; twenty-five times as great at 50 miles; thirty-six times as great at 60 miles; and forty-nine times as great at 70 miles. In other words, at 70 miles per hour, the brake has to do forty-nine times as much work to stop the train as it would at 10 miles per hour.

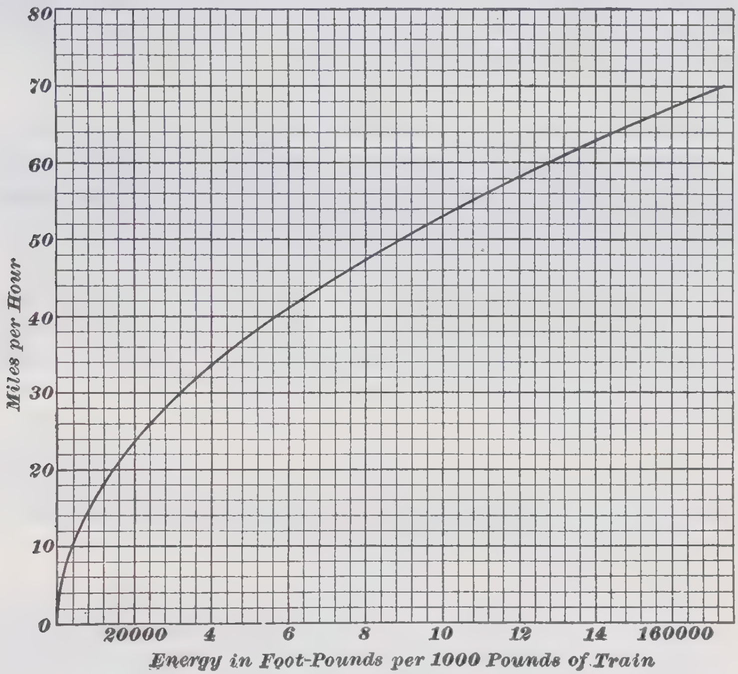


Fig. 1

3. Suppose that a train weighs 1,650,000 pounds. Then, according to the fourth column of the table, the brake would have to destroy 5,857,500 foot-pounds of energy in stopping the train at 10 miles per hour; whereas, at 70 miles per hour, it would have to destroy 287,017,500 foot-pounds of energy, an amount sufficient to raise the entire train 174 feet vertically in the air. The magnitude of the energy that would have to be destroyed in stopping the train running at a speed of 70 miles per hour is too great to grasp without a special

effort. In order to give an idea of the magnitude, it may be said that if a person were to count 150 in each minute, or 90,000 in 10 hours, he would have to count 10 hours a day at this rate for about 3,189 days, or every day for about $8\frac{3}{4}$ years, to count the number of foot-pounds of energy to be destroyed in stopping the train running at a speed of 70 miles per hour, or 287,017,500. This energy, if converted into heat, would produce 268,917 units of heat, an amount sufficient to raise 2,598 pounds (311 gallons) of water from 70° F. to the boiling point, or to raise the temperature of 16 tons of iron 100° F.

4. To destroy, within a distance of less than 1,200 feet and without endangering the safety of the passengers and equipment, the enormous energy stored up in modern trains of heavy cars moving at high speeds, requires a brake of high maximum emergency stopping power; to perform the ordinary service functions and to provide the automatic safety and protective features necessary for a service of this kind, requires a very flexible and efficient service stopping power. It was to provide a brake that would fulfil these requirements that the P C passenger equipment was designed and introduced into service.

DESCRIPTION AND OPERATION

FUNCTIONS AND FEATURES OF THE BRAKE

5. In the P C passenger equipment, the triple valve is replaced by a valve known as a *control valve*, which performs several new functions in the manipulation of the brakes. The features of the brake, as well as the functions performed by it, are as follows:

Graduated release and quick recharge, which are obtained in a manner similar to that of the type L triple valve. A reservoir called the *emergency reservoir* furnishes the air necessary for obtaining the graduated release and for assisting in recharging.

Certainty and uniformity of service action, which is obtained by so designing the parts of the control valve that the feed grooves are closed on the slightest brake-pipe reduction. The

design is such that the differential necessary to move the parts to service position is then built up as the brake-pipe reduction progresses.

Quick rise in brake-cylinder pressure, which is provided for by prompt movement of the parts of the control valve and by direct, unrestricted passages from the reservoirs to the brake cylinders during applications.

Uniformity and maintenance of brake-cylinder pressure during service stops, which is provided for as in the distributing valve of the E T equipment.

Predetermined limiting of the service braking power, which is freed by the equalization of the pressures in the application chamber and the pressure chamber of the control valve. This feature does away with the necessity of the safety-valve feature of the E T and other equipments.

Automatic emergency application on depletion of brake-pipe pressure, which is insured automatically by the movement of the parts of the control valve to emergency position just as soon as the brake-pipe reduction becomes less than the pressure at which the pressure chamber and the reduction-limiting chamber equalize.

Full emergency braking power at any time. The operation of the emergency and quick-action parts of the control valve is such as to give the full emergency braking power whenever the parts move to emergency position. The parts can be moved to emergency position at any time by making an emergency application either with the brake valve or the conductor's valve, or by other means; hence, full emergency braking power can be obtained at any time, even after a full service application has been made.

Separate service and emergency features, thus giving the necessary flexibility for service applications without interfering in the slightest with the emergency features of the equipment.

A low total leverage ratio and greater brake efficiency, due to the use of two brake cylinders on each car. Also, this arrangement gives a higher service equalization pressure.

Less tendency to undesired light applications of the brake, because the apparatus is less sensitive than others to the light

fluctuations of brake-pipe pressure. This insures against brakes creeping on and dragging.

Maximum possible rate of rise of brake-pipe pressure, thus insuring greater certainty of all brakes releasing when a release is made. This is due to the fact that the brake pipe alone has to be charged by the air that flows through the brake valve; the pressure in the pressure chamber of the control valve is restored by air from the emergency reservoir, which raises the pressure at the same rate as brake-pipe pressure up to the point of equalization (about 5 pounds less than normal brake-pipe pressure) of the emergency reservoir and the pressure chamber. After equalization, the reservoir and the pressure chamber are charged up to normal pressure from the brake pipe. This insures a rapid and certain release of all brakes and a rapid recharge and prompt response to succeeding reductions that may be made.

Greatly increased sensitiveness to release, due to the fact, just explained, that the rate of rise of brake-pipe pressure is much greater, because only enough air to charge the brake pipe must flow from the main reservoir through the brake valve to release the brake.

Means of eliminating the graduated release feature during the transition period. This feature is provided so that if a P C equipment is used in a train of cars not so equipped, the graduated-release feature can be quickly and easily cut out.

GENERAL ARRANGEMENT OF THE BRAKE

6. Piping Diagram.—Two piping diagrams showing two methods of arrangement of the P C equipment are shown in Figs. 2 and 3. Fig. 2 shows the arrangement when the two brake cylinders point in opposite directions, whereas Fig. 3 shows the arrangement when the cylinders point in the same direction. The arrangement shown in Fig. 2 permits of a simpler arrangement of the hand-brake rigging; on the other hand, the arrangement shown in Fig. 3 brings, on some cars, the slack adjusters into a more convenient position. The

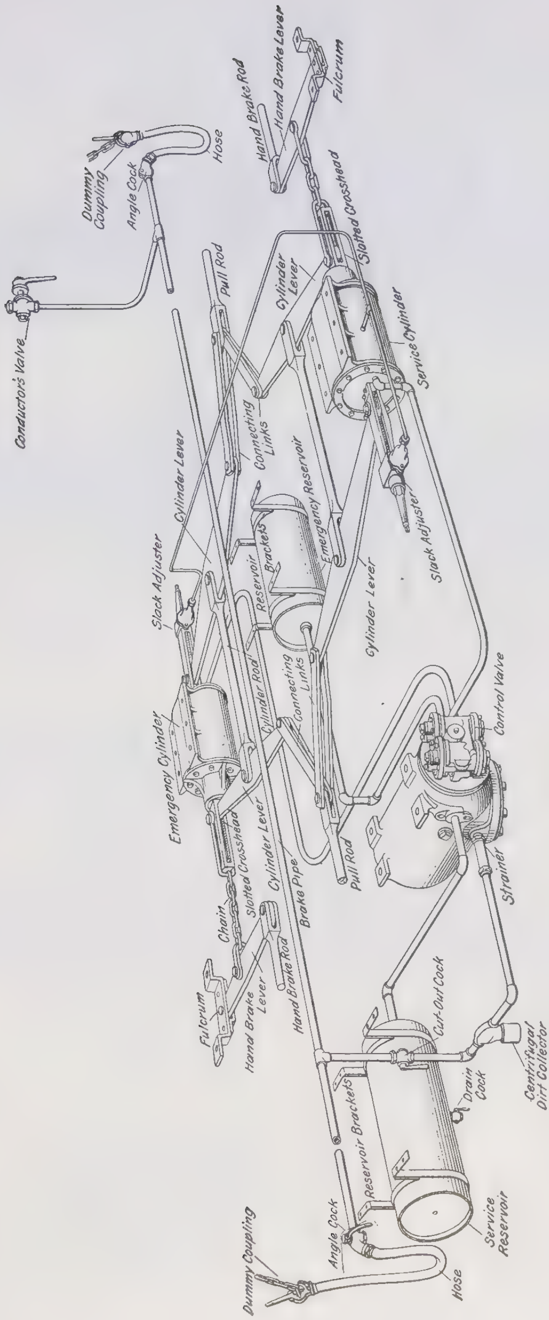

Conductor's Valve
Dummy Coupling
Angle Cock
Hose
Hand Brake Rod
Hand Brake Lever
Fulcrum
Slotted Crosshead
Pull Rod
Cylinder Lever
Service Cylinder
Connecting Links
Emergency Reservoir
Cylinder Lever
Slack Adjuster
Reservoir Brackets
Slack Adjuster
Cylinder Lever
Connecting Links
Cylinder Rod
Emergency Cylinder
Control Valve
Cylinder Lever
Slotted Crosshead
Chain
Brake Pipe
Pull Rod
Strainer
Hand Brake Rod
Hand Brake Lever
Fulcrum
Cut-Out Cock
Centrifugal Dirt Collector
Drain Cock
Reservoir Brackets
Service Reservoir
Angle Cock
Dummy Coupling
Hose

FIG. 2

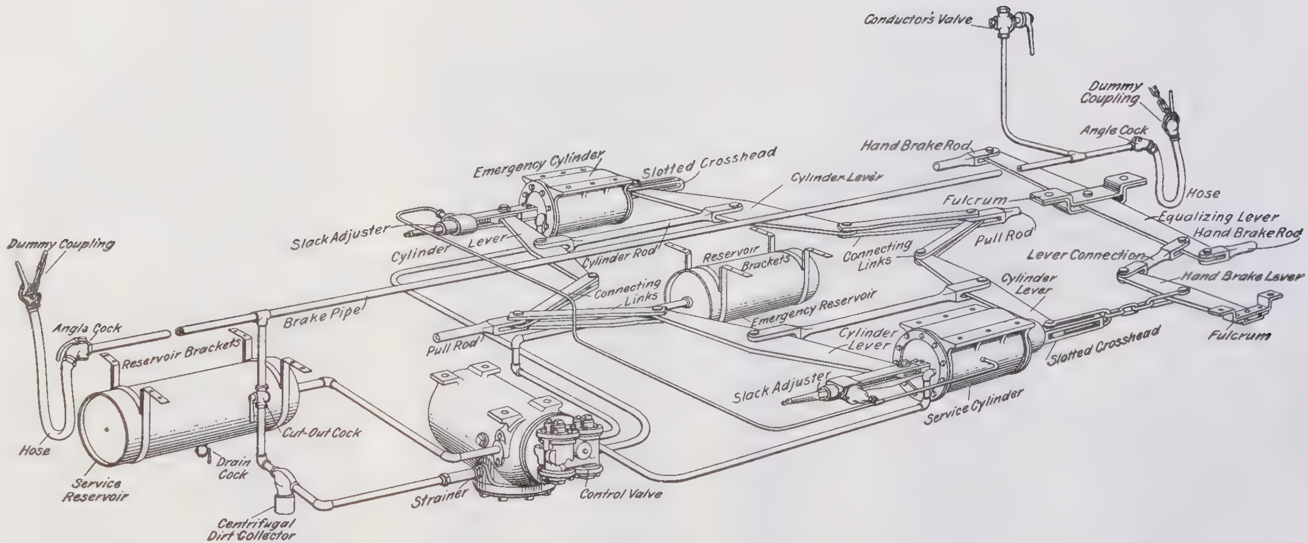

Conductor's Valve
Dummy Coupling
Angle Cock
Hand Brake Rod
Hose
Fulcrum
Equalizing Lever
Hand Brake Rod
Pull Rod
Lever Connection
Hand Brake Lever
Cylinder Lever
Fulcrum
Slotted Crosshead
Service Cylinder
Slack Adjuster
Cylinder Lever
Emergency Reservoir
Reservoir Brackets
Connecting Links
Cylinder Lever
Slotted Crosshead
Emergency Cylinder
Slack Adjuster
Lever
Cylinder
Cylinder Rod
Connecting Links
Pull Rod
Brake Pipe
Dummy Coupling
Angle Cock
Reservoir Brackets
Cut-Out Cock
Hose
Drain Cock
Service Reservoir
Centrifugal Dirt Collector
Strainer
Control Valve

Fig. 3

choice of arrangements, therefore, depends largely on the construction of the underframing of the car and on the location of the apparatus under the car.

7. Two brake cylinders are used on each car. The *service cylinder* is used in both service and emergency applications; the *emergency cylinder* operates during an emergency application, but does not operate during a service application. Thus, in emergency applications, the maximum service braking power is doubled not by increased brake cylinder pressure, as in the other equipments, but by the use of the second cylinder.

Each cylinder is provided with a slack adjuster, and both adjusters are connected to the slack-adjuster hole in the service-brake cylinder; thus, they will operate simultaneously and take the slack up evenly in the two brake cylinders and in accordance with the requirements of the service cylinder.

8. Two reservoirs are used with this equipment. The *service reservoir* supplies air to the service brake cylinder. The *emergency reservoir* supplies air to the emergency cylinder during emergency applications; also, in service operations, it furnishes the air used in obtaining graduated release and quick recharge of the equipment.

A third reservoir, forming part of the control valve, has three chambers called the *pressure chamber*, the *application chamber*, and the *reduction-limiting chamber*.

CONSTRUCTION OF THE CONTROL VALVE

9. External Construction.—The control valve, Fig. 2, takes the place of the triple valve of the older equipments, and, in a general way, corresponds to the distributing valve of the E T equipment. The external construction of the control valve is shown in Figs. 4, 5, and 6; Fig. 4 being a view of the left side of the valve; Fig. 5, a view of the front; and Fig. 6, a view of the right side of the valve, showing the lines of separation of the *equalizing portion*. Fig. 7 shows the equalizing portion *A*, the *reservoir B*, the *quick-action*

portion D, and the *emergency portion E*. It will be observed that the application, quick-action, and emergency portions

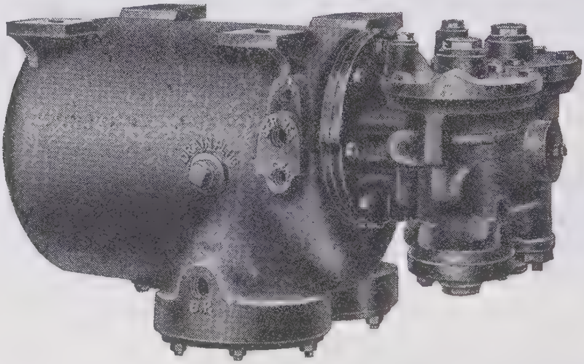


Fig. 4

extend into the reservoir *B* when in place, so that when the control valve is assembled only the flanges of these portions are visible.

Fig. 7 also shows the pipes that should be connected to each of the pipe connections of the reservoir. As will be seen, all connections are made to the reservoir so that no pipe connections need be disturbed to replace any of the four portions of the control valve. In view (*a*), the release-piston graduating nut is shown at *15*, and the check-valve cap nut of the release cylinder of the equalizing portion of the control valve at *17a*. The quick-action-valve cap nut is shown at *137* and the pressure-chamber drain cap nut at *154*. In view (*c*), the emergency-reservoir check-valve cap nut is shown at *17*; the equalizing graduating nut, at *31*; and the cap nut for the small equalizing cylinder cap, at *36*. In view (*b*), the direct and graduated release cap is shown at *18*, and the stud and nut that secures the release cap *18* in the desired position, at *19*. The release cap is shown

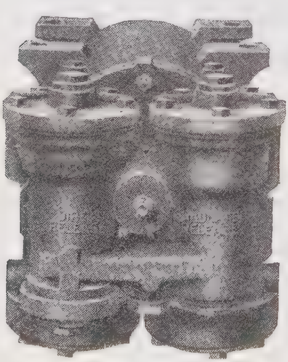


Fig. 5

in position for direct release, in which position the brake cannot be graduated off. To change the control valve so as to give graduated release, loosen the nut of the stud *19* and turn the cap until the indicating finger points to the position marked graduated release; then tighten the nut of the stud *19*. The cap nut *36* is for the small equalizing-cylinder cap.

10. Compartment Reservoir.—Sectional views of the control valve are shown in Figs. 8 and 9 in order to illustrate how the reservoir is divided into compartments. Fig. 8 is a section taken lengthwise through the center line of the reser-

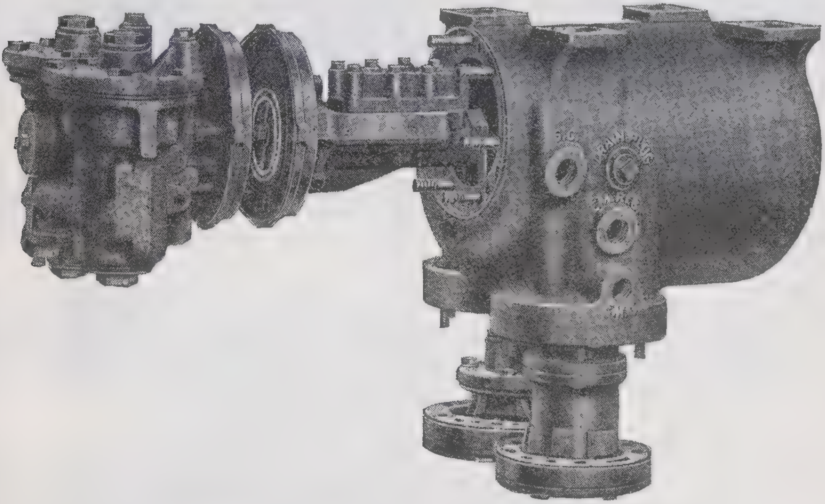


FIG. 6

voir, and Fig. 9 a section taken crosswise of the reservoir on the line *X Y*, Fig. 8, the part to the right of the line being removed and the reservoir turned so as to show the section of the front portion of the reservoir. It will be observed that there are three chambers or compartments in the reservoir.

11. The *application chamber* *X* extends from the partition *a*, Fig. 8, forwards, and also on both sides of the reduction-limiting chamber *Y*, like a pair of saddle bags. There is a drain plug on each side of the compartment reservoir,

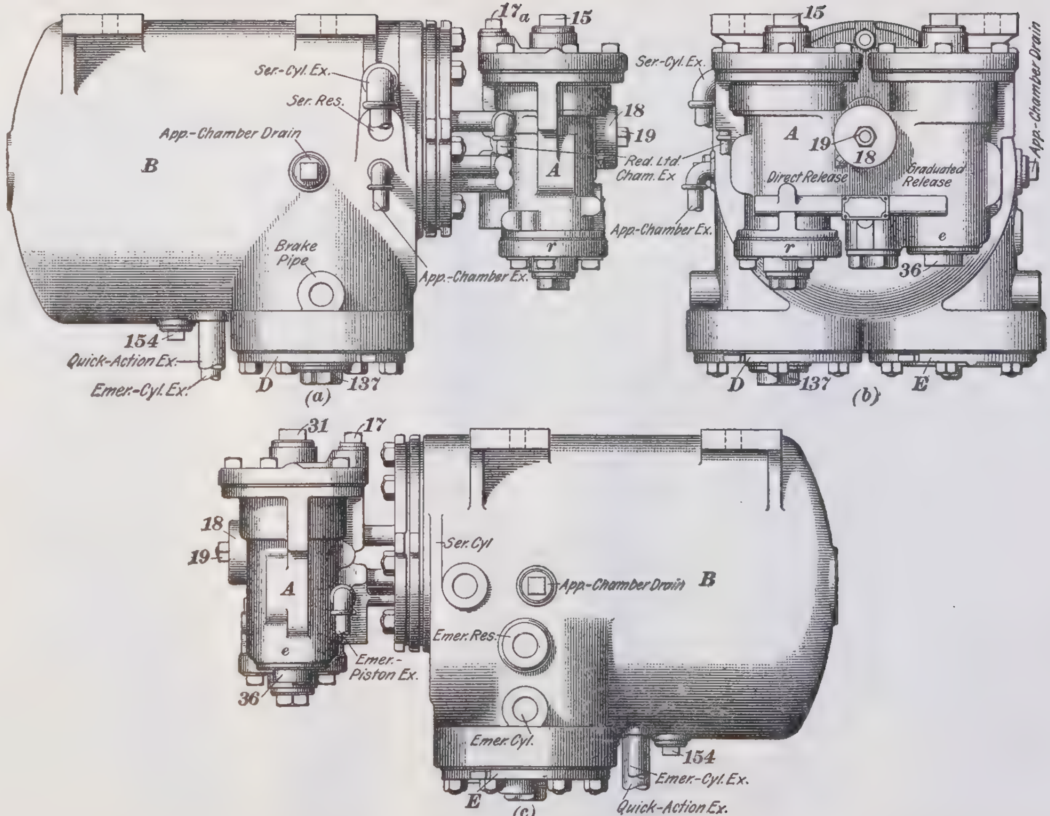

17a
15
Ser.-Cyl. Ex.
Ser. Res.
App.-Chamber Drain
B
18
19
Red. Ltd. Cham. Ex
A
Brake Pipe
App.-Chamber Ex.
r
154
Quick-Action Ex.
Emer.-Cyl. Ex.
D
137
(a)
Direct Release
Graduated Release
App.-Chamber Ex.
e
36
E
(b)
31
17
Ser. Cyl
Emer. Res.
Emer.-Piston Ex.
Emer. Cyl.
(c)

FIG. 7

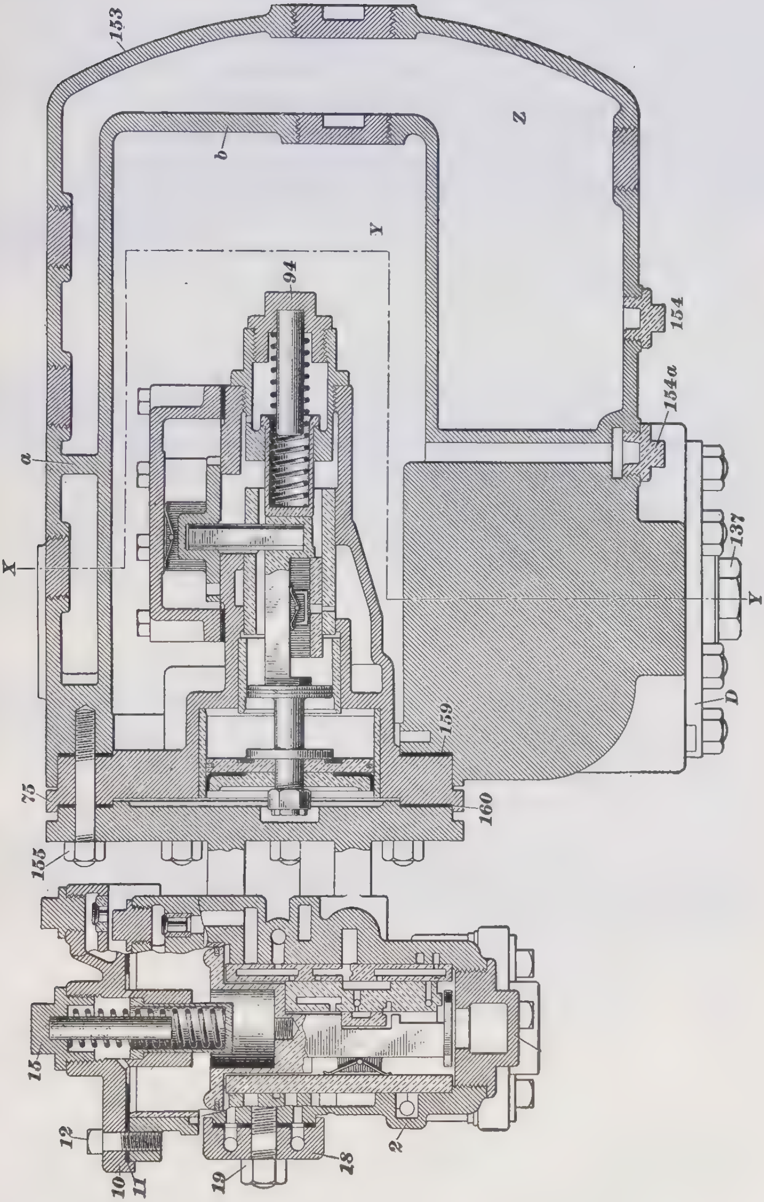


FIG. 8

Fig. 7, so that each leg of the application chamber can be drained. At *157* Fig. 9, is shown the emergency-cylinder gasket; at *158*, the quick-action-cylinder gasket; at *159*, Fig. 8, the large-reservoir gasket; and at *160*, the equalizing-cylinder gasket. The functions of the application chamber are similar to those of the application chamber of the E T equipment.

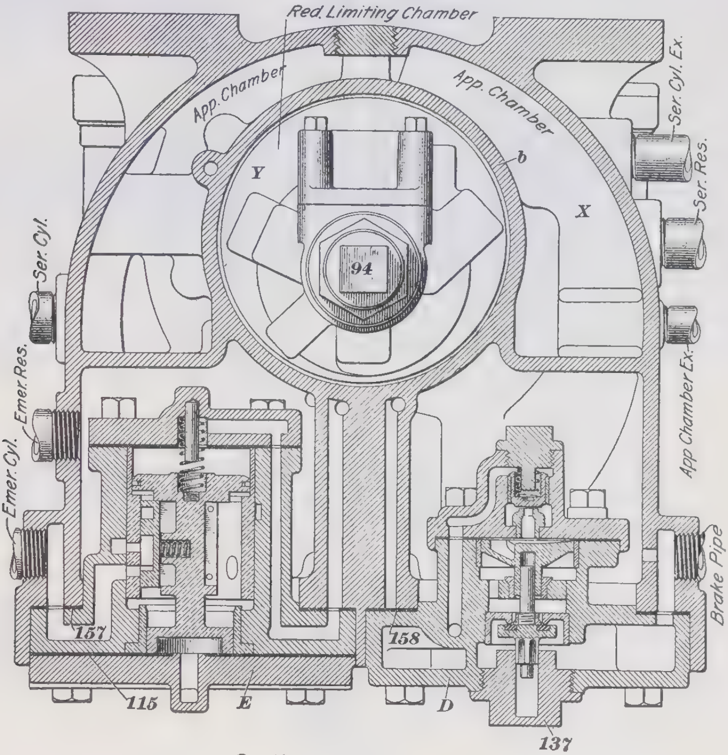
12. The *reduction-limiting chamber Y* is the space contained within the inner reservoir wall *b*. The application portion of the control valve extends into this space, but it is not in any way open to chamber *Y*, as will be seen by an inspection of the general diagram, Fig. 28. The function of the reduction-limiting chamber is to limit the service braking power to a predetermined amount by maintaining the equalization of the pressure and application chambers of the control valve. If, after equalization has taken place, a further brake-pipe reduction occurs, air is automatically vented from the pressure chamber into the reduction-limiting chamber, up to the point of equalization, fast enough to maintain the pressure-chamber pressure constant at the pressure of equalization. This, of course, maintains the application-chamber pressure constant, which automatically maintains the brake-cylinder pressure constant. The capacities of the application and the pressure chambers are such that, with a 24-pound reduction from 110 pounds of brake-pipe pressure, they will equalize at 86 pounds; from 70 pounds of brake-pipe pressure, they will equalize at 54 pounds with a 16-pound reduction.

In Fig. 8, the drain plug for the reduction-limiting chamber is shown at *154a*.

13. The *pressure chamber Z* extends backwards from the partition *a*, Fig. 8, and surrounds the inner-reservoir wall *b*, as shown. The drain plug for this reservoir is numbered *154*.

14. Equalizing Portion.—The **equalizing portion** *A* of the control valve, Fig. 7, consists of two parts: the release portion, and the equalizing portion. In Fig. 7, the cylinder on the left, marked *r*, is the release cylinder, and that marked *e* is the equalizing cylinder.

15. The *release cylinder* is shown in section in Fig. 10, the numbers and names of the parts being as follows: *3*, release piston; *4*, release slide valve; *5*, release slide-valve spring; *6*, release graduating valve; *7*, release graduating-valve spring; *8*, release-piston cap nut; *9*, release piston ring; *10*, release cylinder cap; *11*, release cylinder cap gasket; *12*, capscrew;



Section on X Y of Fig. 8.

FIG. 9

13, release-piston graduating sleeve; *14*, release-piston graduating spring; *15*, release-piston graduating nut; *16*, equalizing check-valve; *17a*, equalizing check-valve cap nut; *18*, the direct and graduated release cap; *19*, the release-cap stud and nut; *45*, the direct and graduated release-cap gasket.

16. The *release slide-valve seat* is shown in Fig. 11. Port *p* leads to chamber *P* of the large emergency piston (follow the ports in Fig. 28); port *j*, to chamber *S* of the small emergency piston; port *e*, to the direct and graduated release cap *18*; ports *Ex*, to the emergency-piston exhaust; port *q*, to the direct

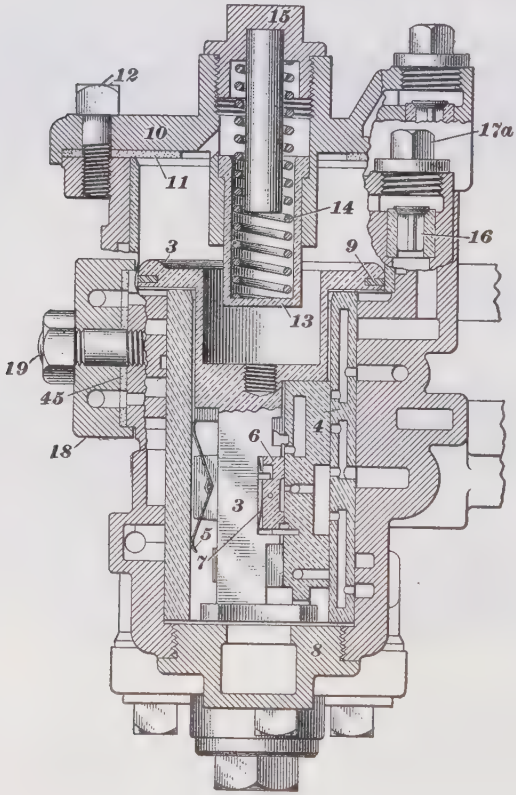


Fig. 10

and graduated release cap; port *l'*, to the application-chamber exhaust and to the direct and graduated release cap; port *l*, to the application chamber; port *r*, to the quick-action closing valve; port *c'*, to the emergency reservoir; and port *i*, to chamber *F* of the small equalizing piston.

17. The *release slide valve* is shown in Figs. 12 and 13. Fig. 13 (*a*) is a sectional view; (*b*), a plan of the face of the valve; (*c*), a plan of the top of the valve; (*d*), a vertical section,

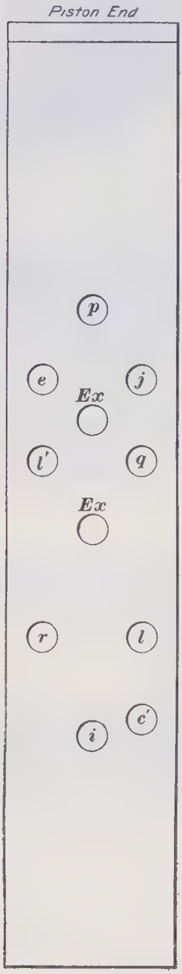


FIG. 11

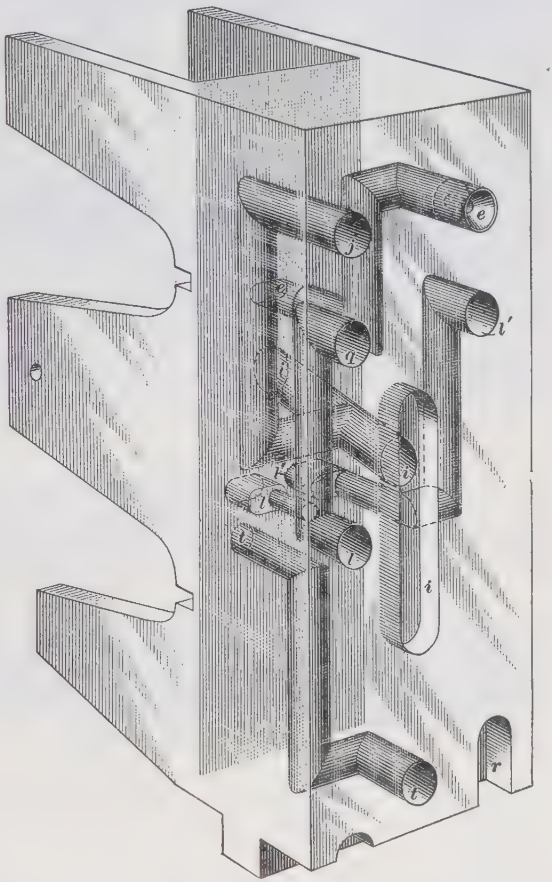
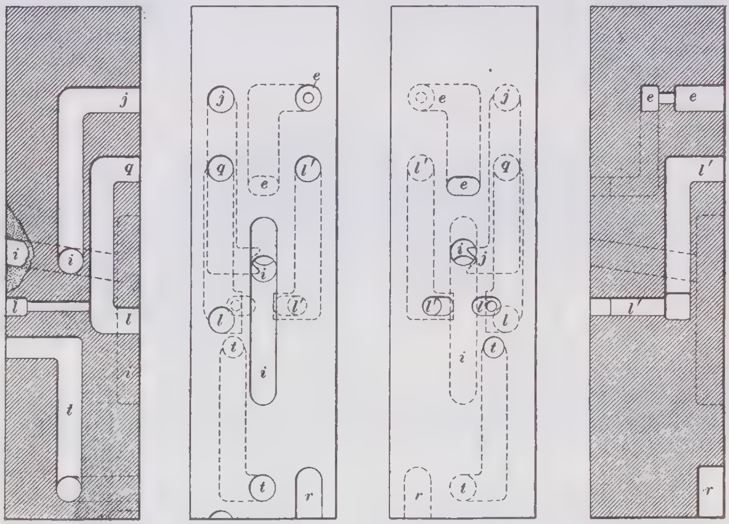


FIG. 12

showing the ports e, l', and r. Port e extends through the valve, as shown. Port i leads from cavity i in the face of the valve to the upper face of the valve; port j, from the face of the valve

into port i; and port l', from the face of the valve to the small port l' in the upper face. Port l connects with port q and leads



(a) (b) (c) (d)

Fig. 13

to the small port l in the upper face. At r is shown a tail-port, or groove, in the end of valve. Port t leads from the face of the valve to the small port t in the upper face.

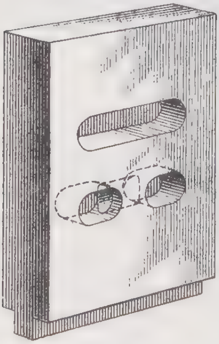


Fig. 14

18. The *release-valve graduating valve*, Fig. 14, merely has two cavities in its face. One of these cavities is always connected to the emergency-piston exhaust in all positions of the valve, so as to release the pressure on that part of the valve and insure sufficient differential pressure on the valve to hold it on its seat at all times.

19. Equalizing Cylinder.—The **equalizing cylinder** is shown in section in Fig. 15, the numbers and names of the parts being as follows: *16a*, emergency-reservoir check-valve; *17a*, emergency-reservoir check-valve cap nut; *20*, equalizing

piston; *21*, equalizing-piston ring; *22*, equalizing slide valve; *23*, equalizing slide-valve spring; *24*, equalizing graduating valve; *25*, equalizing graduating-valve spring; *26*, large equalizing-cylinder cap; *27*, large equalizing cylinder cap gasket; *28*, capscrew; *29*, equalizing-piston stop-sleeve; *30*, equalizing-

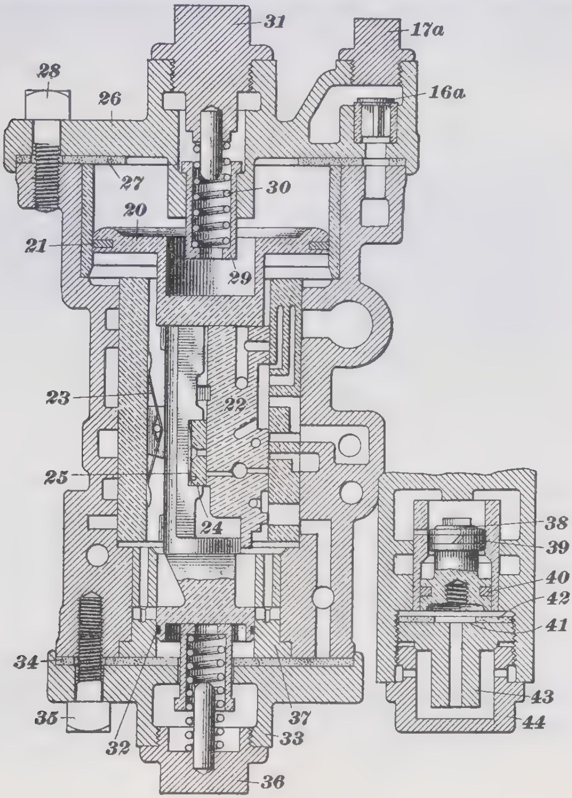


Fig. 15

piston stop-spring; *31*, equalizing graduating nut; *32*, equalizing-piston ring; *33*, small equalizing-cylinder cap; *34*, gasket for small equalizing-cylinder cap; *35*, capscrew; *36*, cap nut for small equalizing-cylinder cap; *37*, small equalizing-piston bush; *38*, service-reservoir charging valve; *39* and *40*, charging-valve piston ring; *41*, charging-valve seat; *42*, charging-valve washer; *43*, internal charging-valve nut; *44*, external charging-valve nut.

20. The *equalizing slide-valve seat* is shown in Fig. 16. Port *c* leads to the emergency reservoir; port *c'*, to the under side of the emergency-reservoir check-valve (trace the ports in the diagram, Fig. 28); port *b*, to the brake-pipe through chamber *B*; port *e*, to the direct and graduated release cap *18*; port *w*, to the reduction-limiting chamber exhaust; and port *v*, to chamber *G*, the small end of the service-reservoir charging valve. Ports *m* unite and lead to the reduction-limiting chamber *Y*. Port *x* leads to chamber *K*, the large end of the service-reservoir charging valve; port *y*, to chamber *E* of the release slide-valve chamber; port *l*, to chamber *C*, the application chamber, and the front of application piston; port *c'*, to the emergency reservoir; port *f*, to the pressure chamber *Z*; and port *i*, to chamber *F* of the small equalizing piston. The slotted tail-port in the end of the valve is shown at *d*.

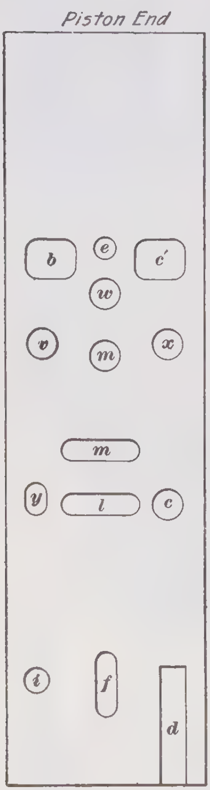
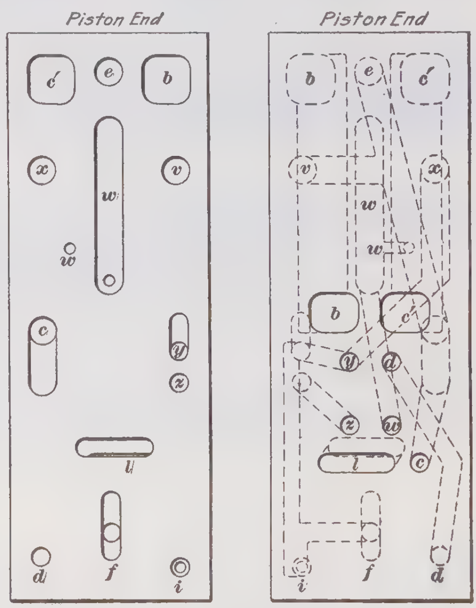


Fig. 16



(a) Fig. 17 (b)

21. The *equalizing slide valve* is shown in Fig. 17, (*a*) being a view of the face of the valve and (*b*) a view of the top of the valve. There are so many ports in this valve and they are so intertwined that it is impossible to make one illustration that will show the relations of all the ports. The views in Fig. 17, therefore, will be used to show the exact relation of the ports on the two faces of the slide valve, and Figs. 18 to 21,

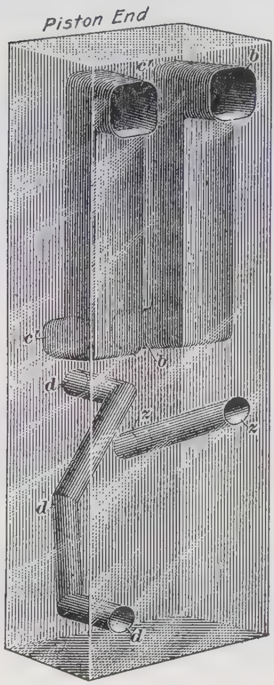


FIG. 18

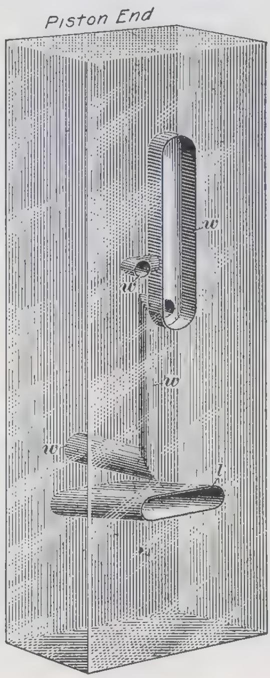


FIG. 19

inclusive, will be used to show the ports that connect with each other and at the same time show how they are situated in the valve.

Fig. 18 shows how the ports b, c', d, and z pass from the lower to the upper face of the valve without connecting with any other port or passage. Ports b and c' pass through the valve in a similar manner.

Fig. 19 shows the location of ports *w* and *l* and illustrates how they too pass through the valve without connecting with other ports or passages.

Fig. 20 shows how port *c* leads from the bottom face of the valve to the top face, and how it connects with the ports *e* and *v* of the valve.

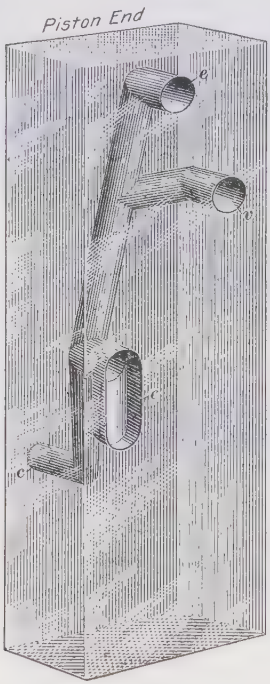


Fig. 20

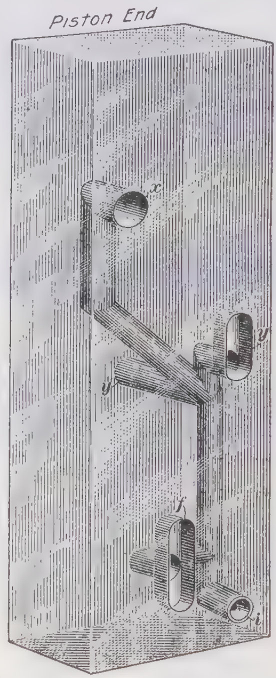


Fig. 21

Fig. 21 shows how the port *y* passes from face to face of the valve and connects with the ports *f*, *i*, and *x*. It will be noted that port *i* is bushed, or restricted, at the lower face of the valve.

The equalizing graduating valve is shown in Fig. 22, *d w* being simply a cavity in the face of the valve.

22. Application Portion.—The **application portion** is shown in section in Fig. 23. The numbers and names of the parts are: *75*, body; *76*, piston stem; *77*, small-piston ring; *78*,

piston head; *79*, piston seat; *80*, large-piston ring; *81*, piston follower; *82*, piston packing leather; *83*, packing-leather expander; *84*, piston nut; *85*, piston cotter; *86*, exhaust valve; *87*, exhaust-valve spring; *88*, application valve; *89*, application-valve spring; *90*, application-piston bolt; *91*, spring box; *92*, piston-spring sleeve; *93*, piston spring; *94*, graduating nut; *95*, application-valve cover; *96*, valve-cover gasket; and *97*, screws for application valve cover.

Fig. 22

It will be observed that the construction and operation of this portion of the control valve is similar to the construction and operation of the application portion of the distributing valve of the E T equipment.

23. Emergency Portion.—The **emergency portion** of the control valve [marked *E*, Fig. 7 (*b*)] is shown in section in Fig. 24. The numbers and names of the parts are: *107*, body;

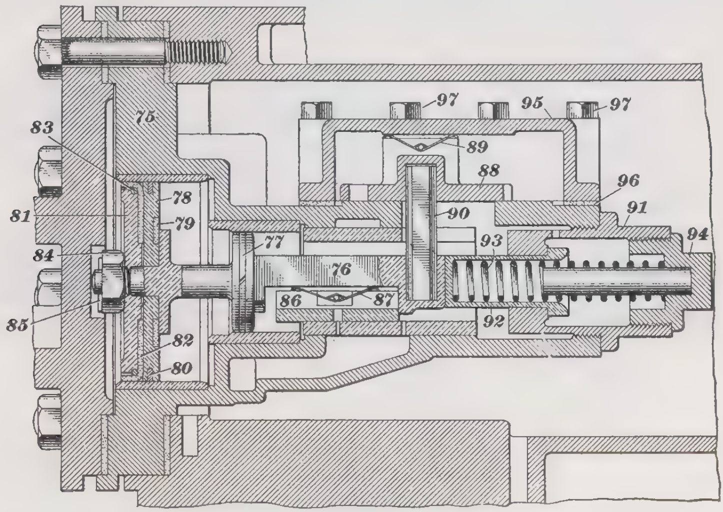


Fig. 23

108, piston (complete); *109*, piston ring; *110*, emergency slide valve; *111*, slide-valve spring; *112*, cap of small cylinder; *113*,

cap of large cylinder; *114*, small-cylinder cap gasket; *115*, large-cylinder cap gasket; *116*, piston spring; *117*, small-cylinder capscrew; *118*, oval fillister-head capscrew; *119* emergency piston bush; and *157*, gasket.

24. The *emergency slide valve and seat* are shown in Fig. 25, in which view (*a*) shows the valve seat and (*b*) the slide valve.

In view (*a*), port *n* leads to the service brake cylinder (trace the ports in Fig. 28); port *e n*, to chamber *M*, back of the application piston; port *o*′, to the emergency-cylinder exhaust; and port *o*, to the emergency cylinder.

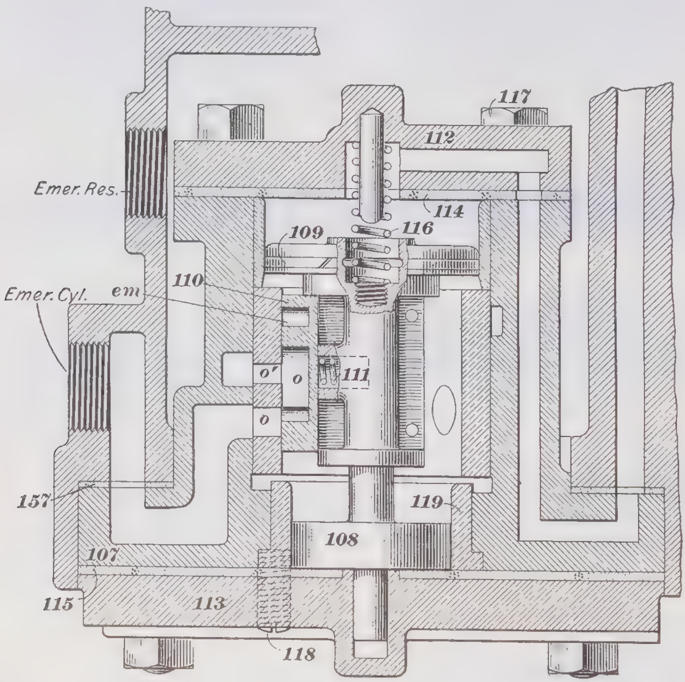
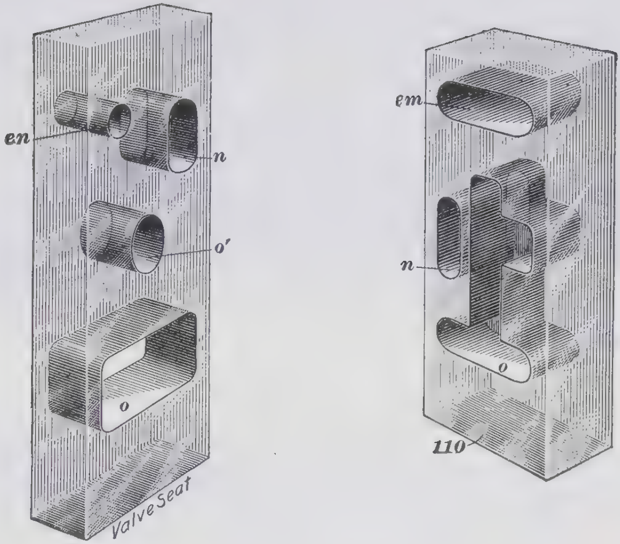


Fig. 24

In view (*b*), port *n* passes through the valve. Both *e m* and *o* are cavities in the face of the valve.

25. Quick-Action Portion.—The **quick-action portion** [marked *D*, Fig. 7, (*b*)] is shown in section in Fig. 26.



(a) Fig. 25 (b)

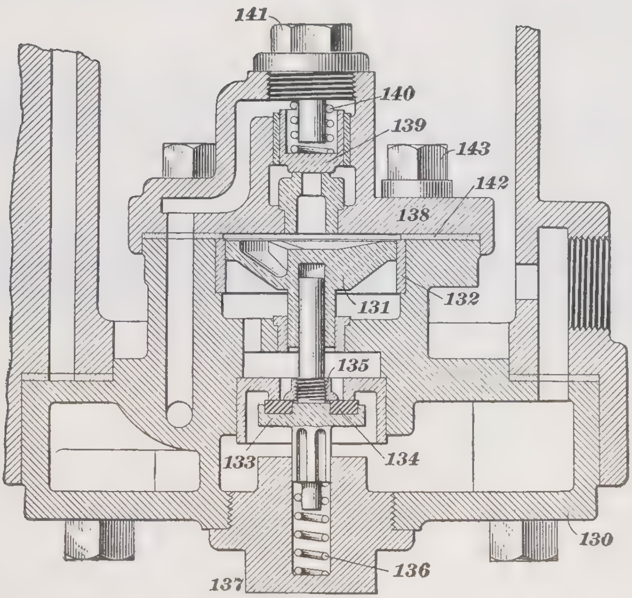
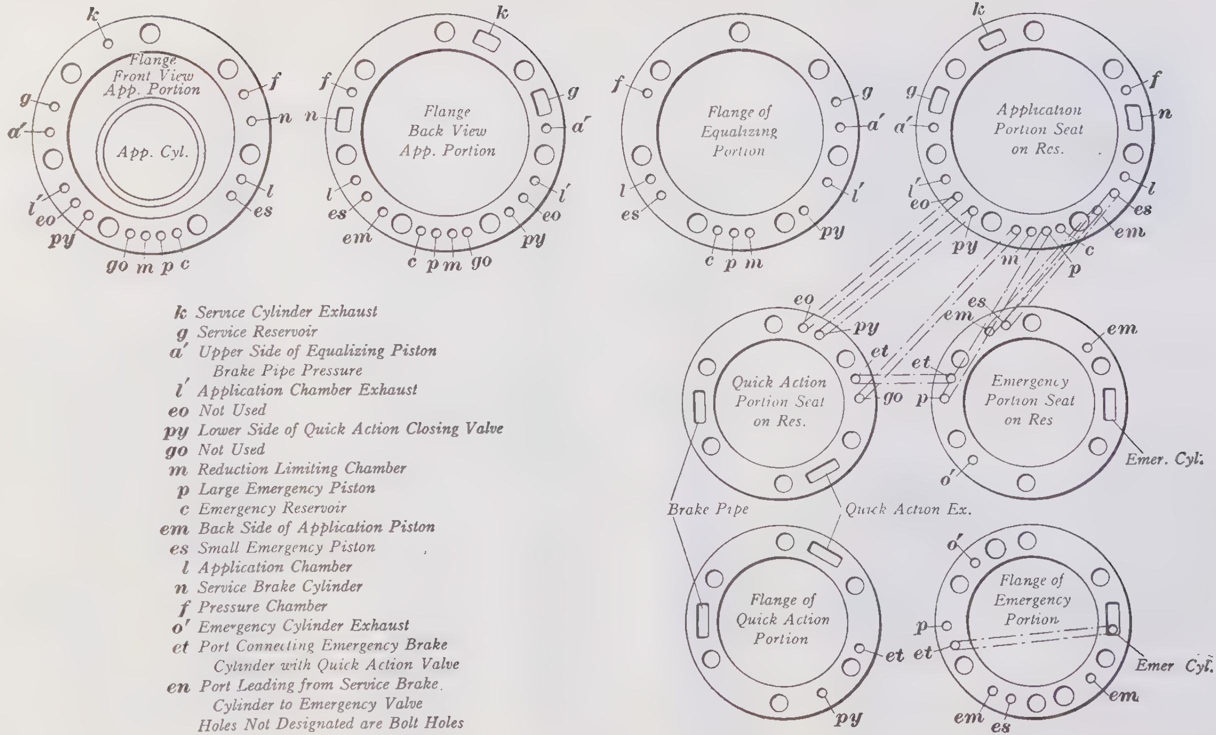


Fig. 26



k *Service Cylinder Exhaust*
g *Service Reservoir*
a′ *Upper Side of Equalizing Piston Brake Pipe Pressure*
l′ *Application Chamber Exhaust*
eo *Not Used*
py *Lower Side of Quick Action Closing Valve*
go *Not Used*
m *Reduction Limiting Chamber*
p *Large Emergency Piston*
c *Emergency Reservoir*
em *Back Side of Application Piston*
es *Small Emergency Piston*
l *Application Chamber*
n *Service Brake Cylinder*
f *Pressure Chamber*
o′ *Emergency Cylinder Exhaust*
et *Port Connecting Emergency Brake Cylinder with Quick Action Valve*
en *Port Leading from Service Brake Cylinder to Emergency Valve*
Holes Not Designated are Bolt Holes

FIG. 27

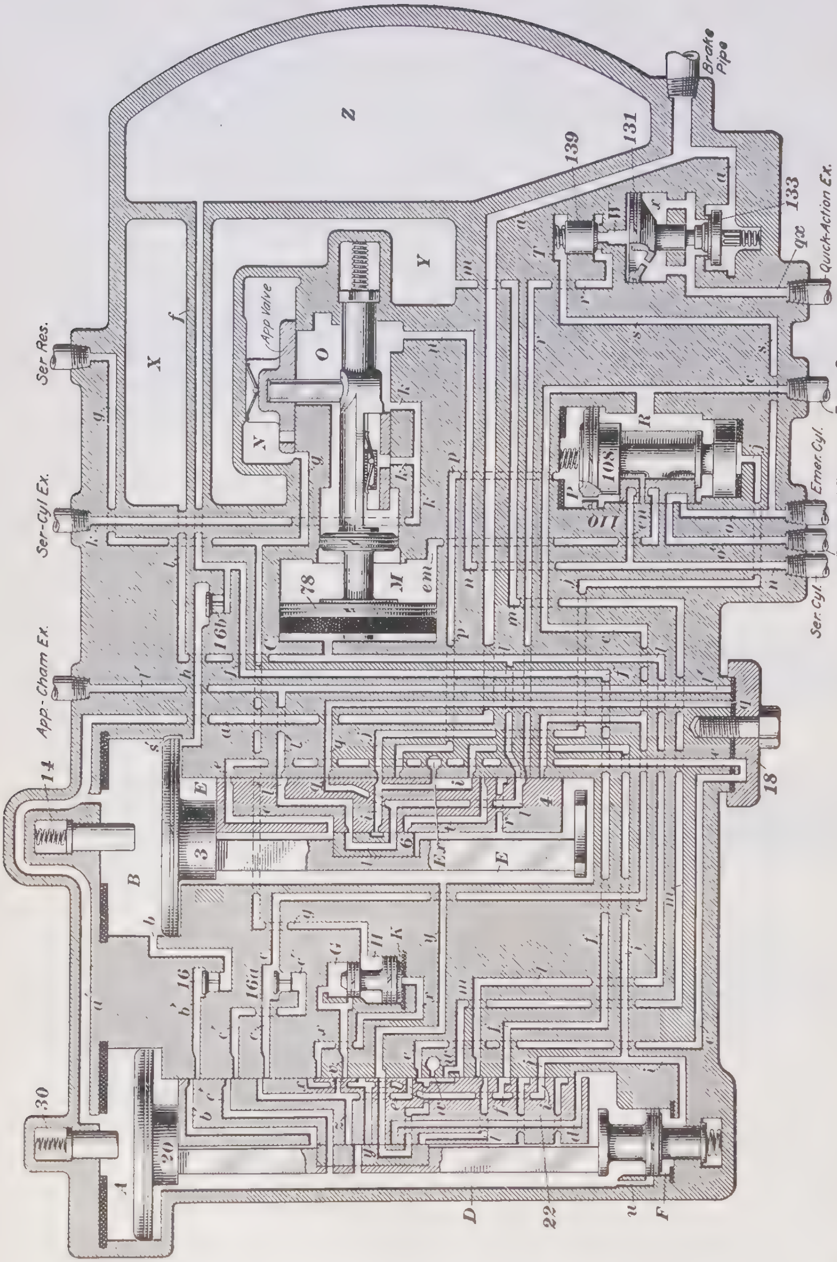
The names and numbers of the parts are: *130*, body; *131*, piston (complete); *132*, piston ring; *133*, quick-action valve; *134*, quick-action-valve seat; *135*, quick-action-valve nut; *136*, quick-action-valve spring; *137*, quick-action-valve cap nut; *138*, quick-action-valve cover; *139*, quick-action closing valve; *140*, closing-valve spring; *141*, cover cap nut; *142*, cover gasket; *143*, cover capscrew.

26. Flange Diagrams.—Fig. 27 shows diagrams of the flanges of the different portions of the control valve and of the seats on which the flanges fit. The diagrams show the locations of the ports in the flanges. Each port is lettered with its proper letter, thus indicating the chamber or part to which the port leads. The path of the ports can be readily traced by referring to the diagram shown in Fig. 28.

OPERATION OF THE CONTROL VALVE

27. Diagrammatic Views.—The control valve contains so many parts, ports, and passages that it would be impossible to describe its operation clearly without the use of diagrammatic views. Furthermore, to indicate all the ports on each diagrammatic view would complicate the views to such an extent as to make the study of the operation of the valve very difficult. The plan, therefore, will be to give first one diagrammatic view, showing all the ports and passages from which a knowledge of the path of each port can be obtained. Then, in studying each position of the control valve, only such ports and passages will be shown as are operative in the position being studied.

28. Uncharged Position.—The positions that all the operative parts of the control valve assume when the brake is uncharged are shown in the diagrammatic view, Fig. 28. After the brake is charged, the parts occupy positions different from these, as will be seen from a study of succeeding views. This view is given in order to indicate the relations of the different ports of the several operative parts of the valve.



Ser Res.
Ser-Cyl Ex.
App-Cham Ex.
App Valve
Brake Pipe
Quick-Action Ex.
Emer. Res.
Emer. Cyl.
Emer-Cyl. Ex.
Ser. Cyl.

FIG. 28

It will be seen in Fig. 28 that port *a* leads from the brake-pipe connection to chamber *Y*, below the quick-action valve *133*; also, that it leads into chamber *B*, ahead of the release piston *3*, and into chamber *A*, ahead of the equalizing piston *20*. Port *b* leads from chamber *B*, through the equalizing check-valve *16*, to port *b* in the equalizing slide-valve seat. Port *c* leads from the face of the equalizing slide-valve seat to the top side of the emergency check-valve *16a*; continuing, it divides and one branch leads to port *c* in the release slide-valve seat, and the other branch leads to chamber *R*, between the two emergency pistons and to the emergency reservoir. Port *c′* leads from port *c′* in the equalizing slide-valve seat to the under side of the emergency check-valve *16a*. Port *e* leads from the equalizing slide-valve seat to the direct and graduated release cap *18*, thence to port *e* in the release slide-valve seat. Port *f* leads from the port *f* in the equalizing slide-valve seat to pressure chamber *Z*; also, it leads to the under side of the pressure-chamber check-valve *16b*. Port *g* leads from the service reservoir into the application chamber *N*; also, a branch leads to chamber *H* between the two pistons of the service-reservoir charging valve. Port *h* leads from chamber *E*, surrounding the release slide valve, to the upper side of the pressure-chamber check-valve *16b*. Port *i* leads from the release slide-valve seat to the port *i* in the equalizing slide-valve seat; also, a branch leads to chamber *F*, surrounding the equalizing piston stop. Port *j* leads from the release slide-valve seat to the chamber below the small piston of the emergency valve *108*. Port *k* connects the two ports in the application-valve seat and leads to the service-cylinder exhaust. Port *l* leads from the equalizing slide-valve seat to the application chamber *X*; also, one branch leads to port *l* in the release slide-valve seat, and a second branch to chamber *C*, ahead of the application piston *78*. Port *l′* leads from the release slide-valve seat to the application chamber exhaust; also, a branch leads to the direct and graduated release cap *18*. Port *m* connects the two ports *m* in the equalizing slide-valve seat and leads to the reduction-limiting chamber *y*. Port *e m* leads from chamber *M*, back of piston *78*, to the emergency

slide-valve seat. Port *n* leads from the service cylinder to chamber *O*, in the application portion; also, it is connected by a branch *e n* with port *e n* of the emergency slide-valve seat. Port *o* leads from the emergency slide-valve seat to the emergency cylinder. Port *o′* leads from the emergency slide-valve seat to the emergency-cylinder exhaust. Port *p* leads from the release slide-valve seat to the chamber *P*, above the emergency piston *108*. Port *q* leads from the release slide-valve seat to the direct and graduated release cap *18*. Port *r* leads from the release slide-valve seat to chamber *W*, below the quick-action closing valve *139*. Port *s* leads from chamber *T*, above the quick-action closing valve *139* into the passage *o*. Port *u* leads from chamber *D* surrounding the equalizing slide valve to such a position in the small equalizing piston bush *37*, Fig. 15, that when the piston is in certain positions, Figs. 28, 32, 33, 34, 35, 36, and 40, the port connects chamber *D* with chamber *F*. Port *v* leads from the equalizing slide-valve seat into chamber *G*, above the small piston of the service-reservoir charging valve. Port *x* leads from the equalizing slide-valve seat to chamber *K*, below the large piston of the service-reservoir charging valve. Port *y* leads from the equalizing slide-valve seat to chamber *E*, surrounding the release valve. Port *q x* leads from chamber *x*, below the quick-action piston *131*, to the quick-action exhaust. It will be noted that the direct and graduated release cap is in the position for graduated release in all positions except that shown in Fig. 41.

29. Release and Charging Position. In the release and charging position of the control valve, Fig. 29, the parts are in position to release the brake and to charge the pressure chamber and the emergency and the service reservoir.

In charging the equipment, Fig. 28, air enters at the brake-pipe connection and passes through port *a* into chamber *B* and chamber *A*, thereby forcing the equalizing piston *20* to release position, Fig. 29. This causes port *b′* of the equalizing slide valve to register with port *b′* of the valve seat, and permits brake-pipe air to pass from chamber *B*, through port *b*, the equalizing check-valve *16*, and ports *b′*, into chamber *D*.

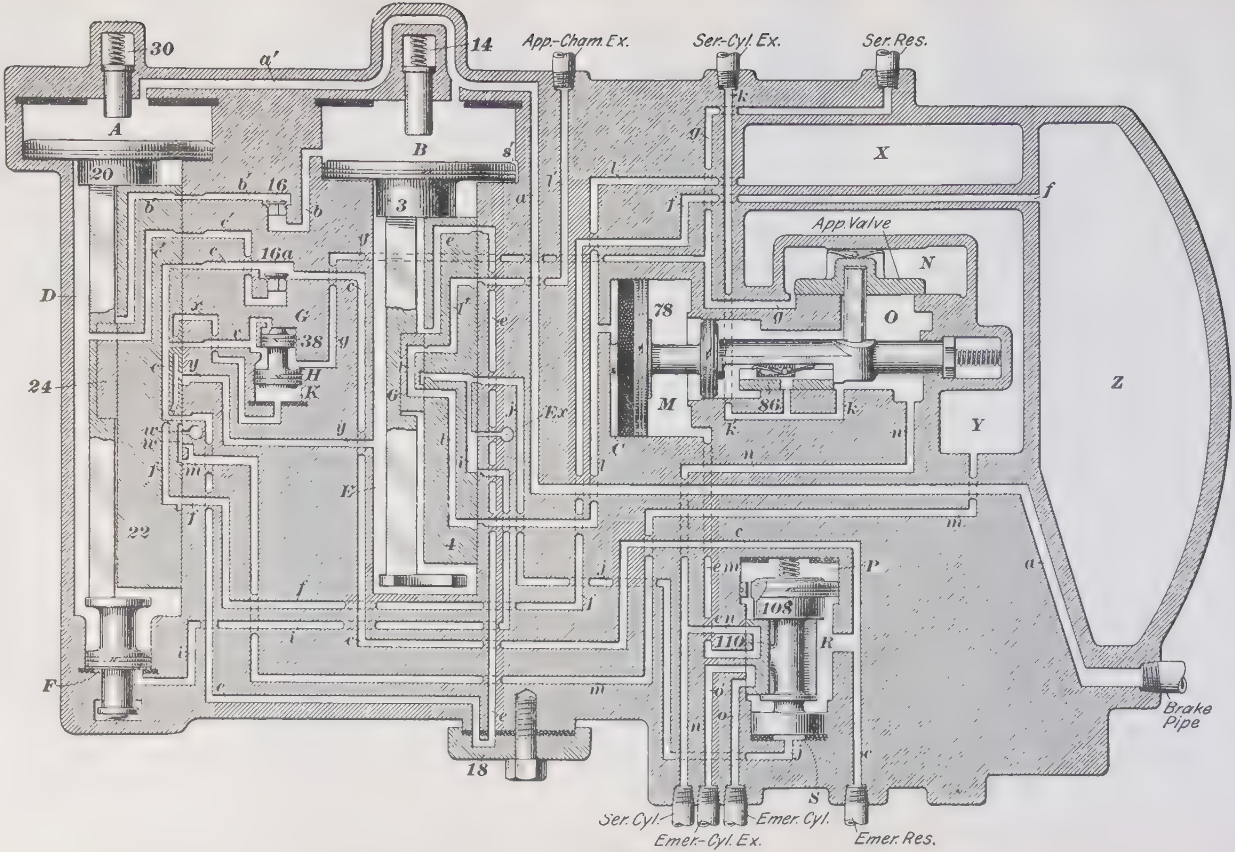

App.-Cham. Ex.
Ser.-Cyl. Ex.
Ser. Res.
App. Valve
Brake Pipe
Ser. Cyl.
Emer.-Cyl. Ex.
Emer. Cyl.
Emer. Res.

FIG. 29

It will be noted that there is no feed groove for piston *20*. Also, port c' of the slide valve registers with port c' in the seat, so that air from chamber D flows through ports c', raises the emergency-reservoir check-valve *16a*, and passes through port c to chamber R and to the emergency reservoir. Some of the air that passes the check-valve *16a* flows through port e of the slide valve *22* and port e of the valve seat to the direct and graduated release cap *18*, thence through port e in the release slide valve into chamber E, as shown. In passing through port e of the slide valve *22*, part of the air branches off at port v and passes through chamber H of the service-reservoir charging valve and port g to the service reservoir and to chamber N in the application portion.

From chamber B, brake-pipe air also flows through the feed groove s' into chamber E, so that this chamber charges by two paths. Air from chamber E passes through port y, thence through port f of the slide valve *22*, and through port f of the valve seat direct to the pressure chamber Z, charging this chamber to brake-pipe pressure. Part of the air passing through port y of slide valve *22* passes through port x of the slide valve and seat into chamber K below the large piston of the service-reservoir charging valve. This gives brake-pipe pressure in both chambers G and K and a service-reservoir pressure, which is much lower, in chamber H, so that the service-reservoir charging valve is held in the position shown until recharging is completed by the greater upward pressure on the large piston. The chamber K is relatively small and the ports leading to it are large enough to charge it more quickly than the chambers G and H.

Chamber F, at the small end of the equalizing piston is connected to the atmosphere through the port i, cavity i in the release slide valve, and the emergency piston exhaust Ex, thereby removing the pressure on the small piston that tends to force the piston forwards. This makes the force of the pressure in chamber A on the big piston that tends to hold the piston in position, greater than the force on the piston due to the pressure in chamber E that tends to move the equalizing piston forwards, so that the piston is held in the position shown.

Chamber *S* is connected to the atmosphere through port *j*, the cavity *i* in the release slide valve *4*, and the emergency piston exhaust *Ex*. This removes the pressure on the lower end of the small piston and makes the force of the pressure in chamber *P* greater than the force in chamber *R* that tends to move the emergency piston, so that the piston is held in the position shown.

The reduction-limiting chamber *Y* is connected to the atmosphere through the port *m*, the cavity *w* in the slide valve *22*, and the reduction-limiting chamber exhaust *w*.

The application chamber *X* and the chamber *C* ahead of piston *78* are connected to the atmosphere through port *l*, port *l* in the release slide valve *4*, port *l'*, and the application-chamber exhaust.

The service cylinder and chambers *M* and *O* are connected to the atmosphere through ports *n*, *e m*, and *e n*, chamber *O*, port *k*, and the service-cylinder exhaust.

The emergency cylinder is connected to the atmosphere through port *o*, the cavity in the emergency slide valve, port *o'*, and the emergency cylinder exhaust *Ex*.

The small cavity in the release graduating valve is connected to the atmosphere through port and cavity *i* in the slide valve *4* and the emergency piston exhaust *Ex*. This relieves the face of the graduating valve of sufficient pressure to insure the graduating valve being held firmly on its seat under all conditions.

30. Preliminary Service-Application Position.—A reduction in brake-pipe pressure lowers the pressure in chambers *A* and *B* below that in chambers *D* and *E*, thus tending to move both the pistons *20* and *3* forwards from release position. Piston *3* moves with a less differential pressure, however, owing to the fact that chamber *F* at the small end of the piston *20* is open to the atmosphere in release position, thus reducing the area that chamber-*D* pressure acts on. A greater reduction in brake-pipe pressure, therefore, is necessary to move piston *20* than to move piston *3*, so that during a brake-pipe reduction piston *3* moves first. There is a small amount

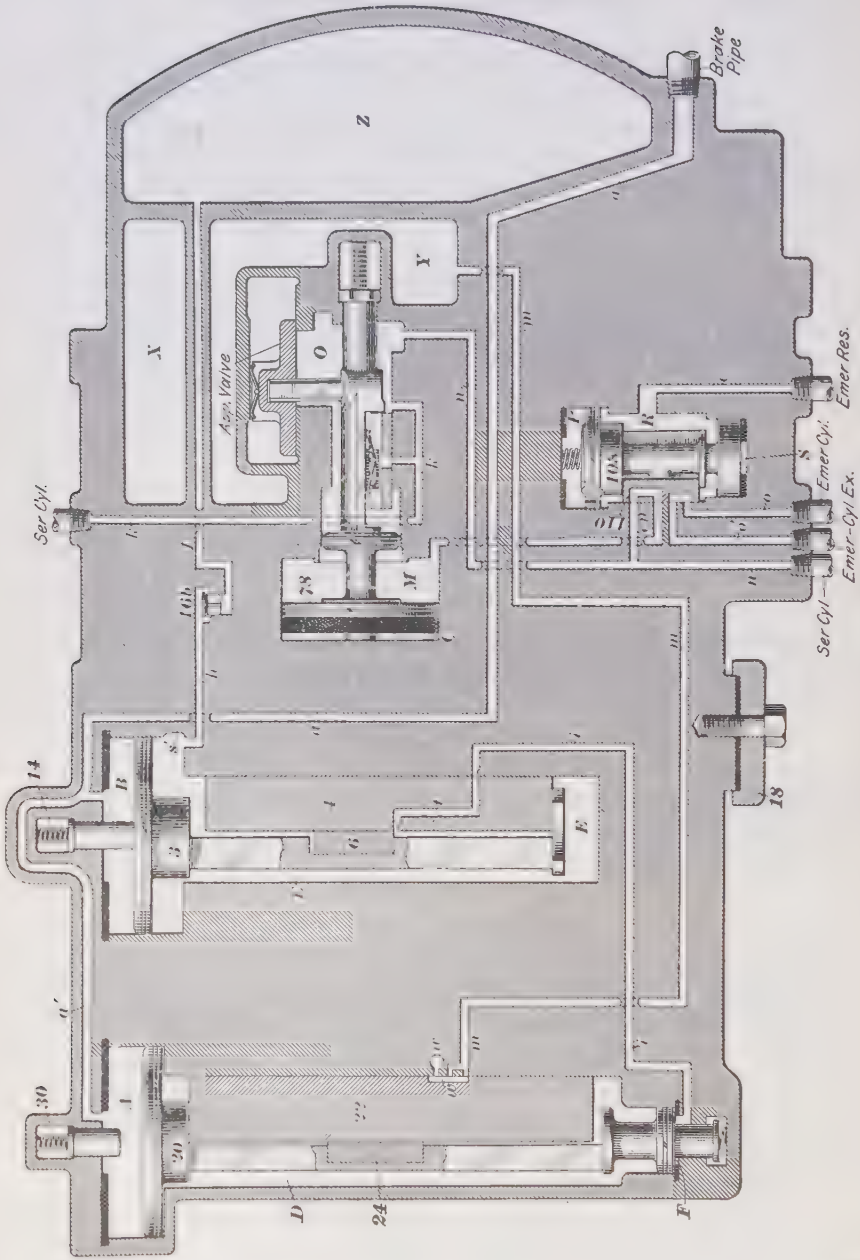
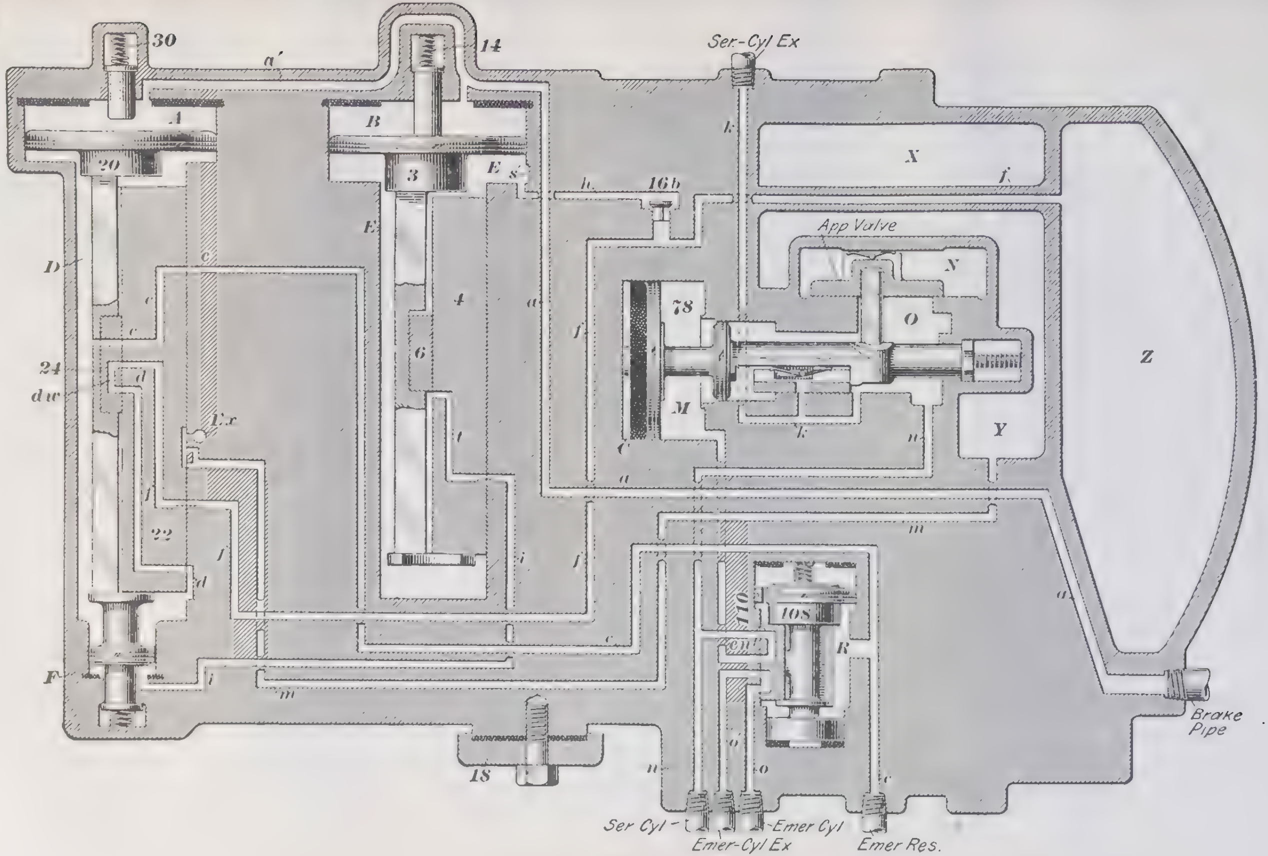

Brake Pipe
Z
X
Y
O
App. Valve
Ser Cyl.
Emer Res.
Emer Cyl.
Emer-Cyl Ex.
Ser Cyl
M
78
16b
14
B
E
18
30
20
22
D
24
F

FIG. 30



30
14
a′
A
B
20
3
E
s
h
16b
k
X
f
Z
Ser-Cyl Ex
App Valve
N
O
78
M
C
Y
D
c
4
6
24
d
dw
Ex
t
22
j
i
F
m
18
n
110
108
R
o
a
Ser Cyl
Emer Cyl
Emer-Cyl Ex
Emer Res.
Brake
Pipe

Fig. 31

of space between the graduating valve and the release piston, and considerably more between the release slide valve and the release piston. When sufficient brake-pipe reduction is made to overcome the friction of the piston *3*, the piston moves forwards, and when it strikes the graduating valve it moves that valve forwards, until, finally, it strikes against and moves the slide valve to the position shown in Fig. 30. This is called the *preliminary service position*, and the parts assume this position only momentarily on their way to *service position*. In this position, the piston *3* has moved past the feed groove s' and has come to rest against the release graduating sleeve *14*, as shown.

In moving the slide valve, port l, leading from the application chamber to the application-chamber exhaust, is closed. The reduction-limiting chamber Y, the service cylinder, the emergency cylinder, and the chambers O and M are all still open to the atmosphere. The connection between chamber F and the atmosphere is now closed, and chamber F is connected through port i and port t of the release slide valve with chamber E, and thence through port h, check-valve *16b*, and port f, with the pressure chamber Z, thus charging chamber F to pressure-chamber pressure and equalizing the pressures on the two faces of the small piston.

31. Secondary Service-Application Position.—The instant that the pressures on the two faces of the small piston of the equalizing valve are equalized, the pressure in chamber D exerts a force on piston *20* that is greater than that of the pressure in chamber A; hence the equalizing valve is moved forwards toward service position. During this movement it momentarily assumes *secondary service position*, Fig. 31. In this position, the shoulder on the end of the piston stem is just against the slide valve *22*; also, port e of the slide valve registers with port c, and the graduating valve uncovers port c in the top of the slide valve (see Fig. 20), so that there is a momentary connection between the emergency reservoir and chamber D while the slide valve is moving past the secondary service position. The object of this is to charge cham-

ber *D* from the emergency reservoir an amount sufficient to compensate for the increase in volume in chamber *D* as the piston *20* moves forwards to service position, and thus prevent a drop in chamber-*D* pressure due to the increased volume. Also, momentary connection is made between chamber *D* and the pressure chamber *Z* through the groove *d* in the equalizing-valve seat, Fig. 16; port *d* in the valve face, Figs. 17 and 31; the cavity *d w* in the graduating valve; and ports *f* in the slide valve and seat. This prevents chamber *D* from being highly overcharged and maintains the pressures in chambers *D* and *Z* equal. The pressure in chamber *E* is maintained equal to the pressure in chamber *Z* through port *f*, check-valve *16b*, and port *h* as the piston *3* moves forwards. In fact, during an application of the brakes, this connection practically makes chambers *E* and *Z* but one chamber in volume; that is, during a reduction the connection through the check-valve *16b* maintains the pressure equal in the two chambers, so that to reduce the pressure in chamber *E*, the pressure in chamber *Z* must be reduced a like amount. The relations between the other ports, parts, and chambers are the same as in Fig. 30.

32. Service Position.—The piston *20* moves forwards from secondary service position to service position, Fig. 32, where it is stopped by the equalizing graduating spring *30*. In this position, port *u* connects chambers *D* and *F*, thus equalizing the pressures in the two chambers.

The pressure chamber has a direct connection to chamber *D* by way of port *f* and a port through the equalizing slide valve *22*. Also, it has an indirect connection with chamber *D* through the check-valve *16b*, port *h*, chamber *E*, port *t* of the slide valve *4*, and port *i*; port *i* divides, one branch leading to chamber *F* and the other to a port in the equalizing slide valve. These two paths make provision for a considerable volume of air to flow from the pressure chamber into chamber *D*.

Pressure-chamber air, after flowing to chamber *D*, can pass through port *l* in the slide valve *22* and port *l* in the valve seat to chamber *C* ahead of the application piston *78*, and to the

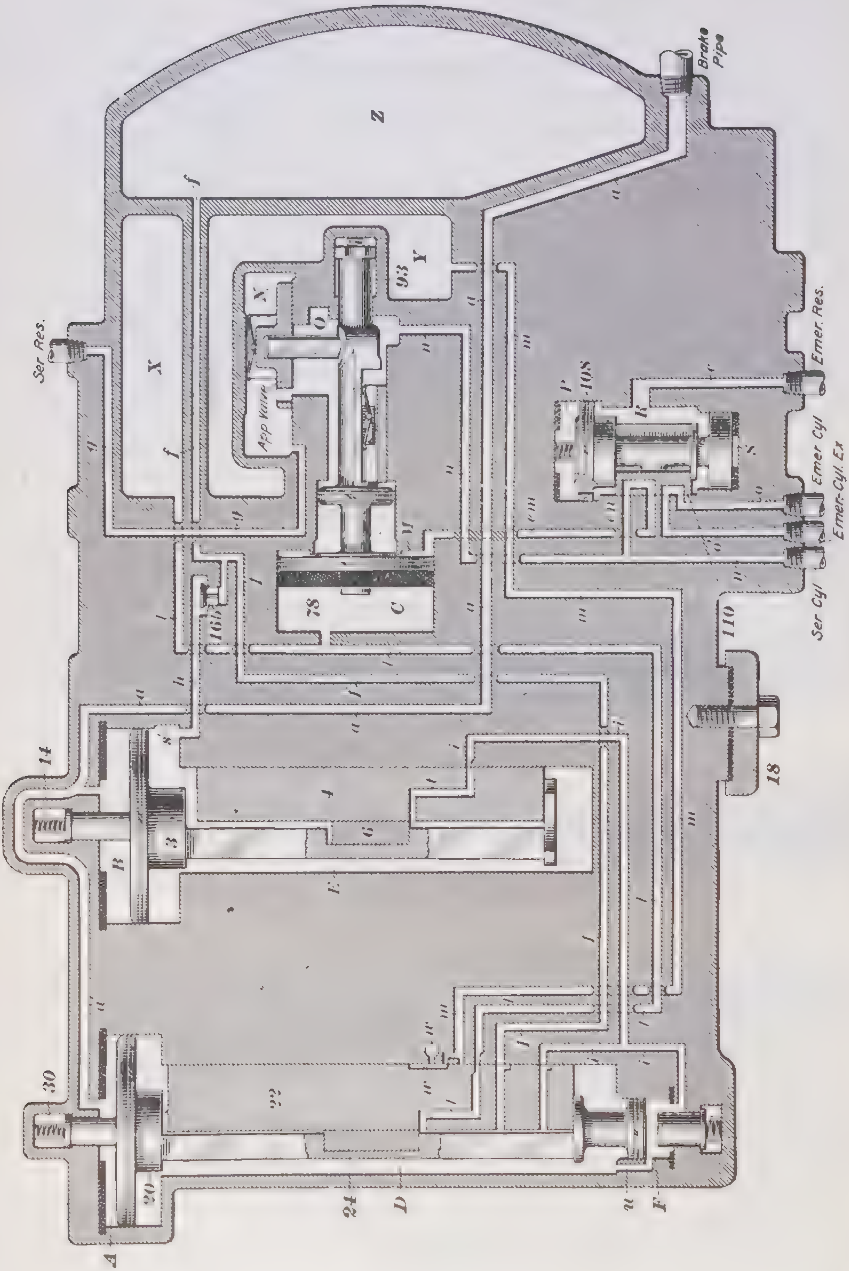

Ser Res.
Brake Pipe
Emer. Res.
Emer Cyl
Emer-Cyl. Ex
Ser Cyl
App Valve
Z
X
Y
93
N
O
P
108
R
S
78
C
16b
14
B
3
4
6
E
18
110
30
20
22
24
D
u
F
A

FIG. 22

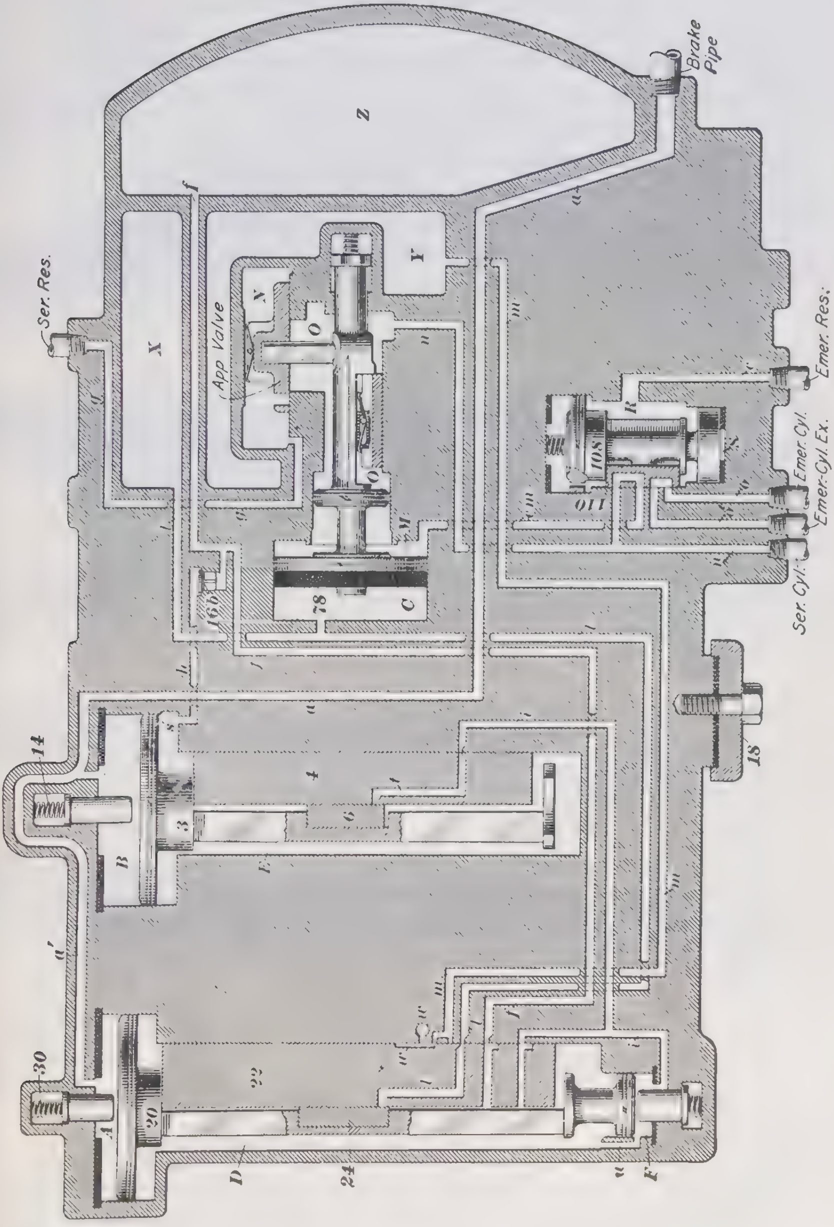

Ser. Res.
Brake Pipe
App Valve
Emer. Res.
Emer. Cyl.
Emer. Cyl. Ex.
Ser. Cyl.
Z
X
Y
N
O
C
78
16b
14
B
3
4
6
E
30
20
A
22
24
D
F
18
R
108
110

Fig. 33

application chamber *X*. The pressure thus admitted into chamber *C* moves piston *78* backwards to its application position, compressing the application-piston spring *93*. In this position, the exhaust valve closes the service-cylinder exhaust ports *k*. For this reason they are not shown in Fig. 32. The port in the application slide valve is opened and permits air from the service reservoir to flow through port *g* and chamber *N* into chamber *O*, and through port *n* to the service brake cylinder, applying the brake with the pressure developed by that cylinder. The pressure in chamber *M* is maintained equal to that in the service cylinder through the port ***e n***, the cavity in the emergency slide valve, and the port ***e m***. Air will continue to flow into the service cylinder and chamber *M* until the pressure becomes about equal to the application-chamber pressure on the other face of the piston *78*, when the application piston spring *93* returns the piston *78* and slide valve back to service lap position, Fig. 33. This holds the brakes applied with a service brake-cylinder pressure about equal to the pressure admitted to chamber *C* and the application chamber. The operation of the application portion of the control valve for all operations of this brake is exactly the same as the operation of the application portion of the distributing valve of the E T equipment.

In service position, the emergency brake cylinder and the reduction-limiting chamber are still open to the atmosphere.

33. Service Lap Position.—As there is direct connection between the chambers *D*, *E*, and *Z* in service position, it follows that any reduction of pressure in chamber *D* will produce a like pressure in chambers *E* and *Z*. When a brake-pipe reduction is made to apply the brake and the parts move to service position, air from chamber *Z* flows by way of chamber *D* into chamber *C* and chamber *X*. The air continues to flow from chamber *D* until the pressure is reduced sufficiently below brake-pipe pressure to overcome the resistance of the piston *20*, when the equalizing valve will be moved back to *service-lap position*, Fig. 33. It makes no difference in the operation of the control valve whether the piston *3* moves to lap position

or not, because it is the equalizing graduating valve that laps port *l*, thus stopping the flow of air into the application chamber *X* and holding the pressure that was built up in chamber *C*. The pressure in chamber *C* determines the pressure in the brake cylinder, because brake-cylinder pressure is automatically maintained equal to chamber-*C* pressure by the application portion, as follows: Any reduction in brake-cylinder pressure reduces chamber-*O* pressure and causes chamber-*C* pressure to force piston *78* backwards and open the port in the application valve. Air from the service reservoir, therefore, flows through chamber *N* into chamber *O* and the brake cylinder until chamber-*O* pressure is enough greater than chamber-*C* pressure to overcome the frictional resistance of the piston *78*, when the application valve closes and cuts off the flow of air to the brake cylinder. The pressure-maintaining feature of the application portion of the control valve is exactly the same as that for the distributing valve of the E T equipment.

It will be noted that both chamber *Y* and the emergency brake cylinder are open to the atmosphere.

34. Overreduction Position.—The pressures in chambers *D* and *E* cannot be reduced below the pressure of equalization of the pressure chamber and the application chamber, which is 86 pounds from a brake-pipe pressure of 110 pounds and 54 pounds from a brake-pipe pressure of 70 pounds. If the brake-pipe pressure is reduced below the pressure of equalization—that is, if an overreduction is made—the equalizing piston will be moved by chamber-*D* pressure beyond its service position to the *overreduction position*, Fig. 34. In this position, the equalizing piston *20* compresses the graduating spring *30* and bottoms against the equalizing-cylinder cap gasket *27*, Fig. 15. Release piston *3* remains in service position owing to the higher resistance of the graduating spring *14*, which is stronger than the spring *30*.

In moving forwards into overreduction position, slide valve *22* is moved so as to close the port *l* leading to the application chamber and to port *l* of the slide valve with port *m* of the seat. Port *m* leads to chamber *Y*, so that on an overreduction

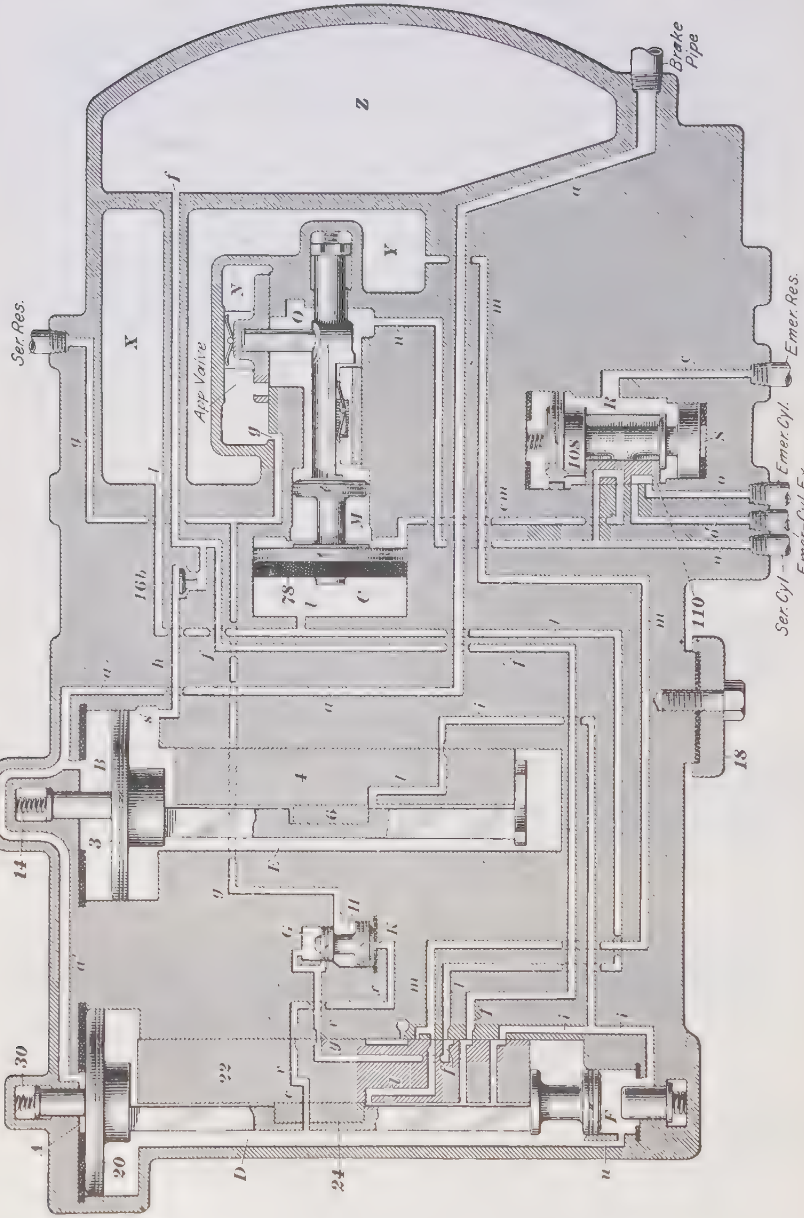

Ser. Res.
Brake Pipe
App Valve
Emer. Res.
Emer. Cyl.
Emer-Cyl Ex
Ser. Cyl
Z
X
Y
N
O
M
C
78
16b
108
110
18
14
30
20
22
24
D

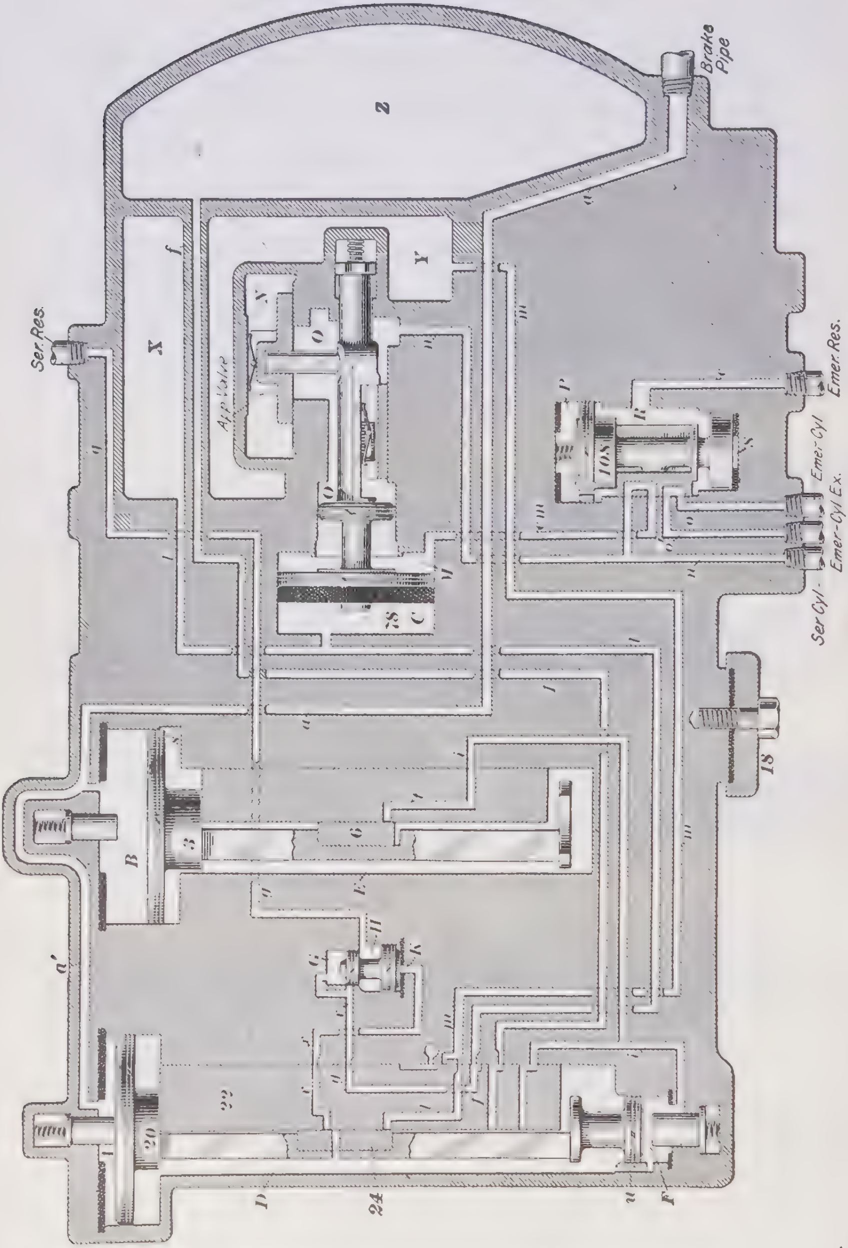
FIG. 34

the air from the pressure chamber flows into the overreduction chamber *Y* instead of into chamber *C* and the application chamber. The pressure in chamber *C* is thus held constant at the pressure at which the pressure chamber and the application chamber equalized; hence, the service brake-cylinder pressure is limited to this amount and maintained equal to it.

The reduction-limiting chamber *Y* is of such size that it will equalize with the pressure chamber at about 60 pounds from a pressure-chamber pressure of 86 pounds, or at about 35 pounds from a 70-pound pressure-chamber pressure.

In the overreduction position, Fig. 34, it will be seen that chambers *C* and *X* are connected through port *l*, ports *f* and *y* of slide valve *22*, and port *v* of the seat with chamber *G*, above the service-reservoir charging valve. Also, pressure chamber *Z* is connected through port *f*, chamber *D*, ports *c* and *v* of the slide valve, Fig. 20, and port *x* of the seat, Fig. 34, with chamber *K* below the service-reservoir charging valve. The pressure in chamber *C* and, therefore, in chamber *G* is maintained constant; the pressure in chamber *K* reduces with the pressure-chamber reduction during an overreduction, thus insuring that the service-reservoir charging valve will be held down on its seat.

The service reservoir, the pressure of which is maintained about equal to chamber-*C* pressure by the pressure-maintaining feature of the application portion, is connected through port *g* with chamber *H*. Any slight leakage from the application chamber in this position of the control valve will be supplied from the service reservoir past the packing ring of the service-reservoir charging valve that separates chambers *H* and *G*. The capacity of the service reservoir is relatively large when compared with the capacity of the application chamber. Therefore, the pressure in the reservoir will be higher than that in chamber *G* when a leak develops. Reservoir air will thus leak past the piston packing ring that separates chambers *H* and *G* and prevent any material drop in chamber-*C* and application-chamber pressure. Maintaining chamber-*C* pressure in this manner practically eliminates the possibility of the brakes gradually leaking off, due to application chamber leak-



Ser. Res.
Brake Pipe
App Valve
Emer. Res.
Emer-Cyl
Emer-Cyl Ex.
Ser Cyl

Fig. 35

age, because the pressure-maintaining feature of the control valve will automatically maintain brake-cylinder pressure equal to chamber-*C* pressure.

35. Overreduction Lap Position.—When an overreduction is made, the piston *20* moves to the position shown in Fig. 34. This connects chamber *D* with chamber *y*, so that the pressure in chambers *D*, *E*, and *Z* gradually reduces by the air discharging into chamber *Y*. When chamber-*D* pressure becomes enough less than chamber-*A* pressure for the latter to overcome the frictional resistance of piston *20*, the piston and the graduating valve *24* will be moved back to *overreduction lap position;* that is, until the shoulder of the equalizing-piston stem strikes against the slide valve *22*, Fig. 35. The graduating valve *24* will then cover or blank port *l* and thus close communication between the chambers *Y* and *Z*. Each succeeding reduction, provided it does not produce equalization between chambers *Y* and *Z*, will cause piston *20* to move to overreduction position and, finally, back to overreduction lap position. Also, in this position, the graduating valve *24* blanks the port *v* leading to chamber *K*. Therefore, in case the brake is held applied in overreduction position for a sufficient lenght of time and the leakage from the application chamber is so great that sufficient service-reservoir air cannot leak past the piston packing ring, from chamber *H* into chamber *G*, to supply it, the service-reservoir charging valve will finally be moved upwards, opening direct connection between the service reservoir and the application chamber through port *g*, chamber *H*, ports *v* and *y*, port *f* in slide valve *22*, and port *l*.

Should an overreduction reduce the brake-pipe pressure below the pressure of equalization of chambers *Y* and *Z*, quick-action would result, as will be explained in connection with the emergency position.

36. Preliminary Release Position.—In releasing brakes, a rise in brake-pipe pressure above the pressure in chambers *D* and *E* will cause the piston *20* to move toward release position. The equalizing piston *20* moves first, because the release piston and valves are designed so that they will

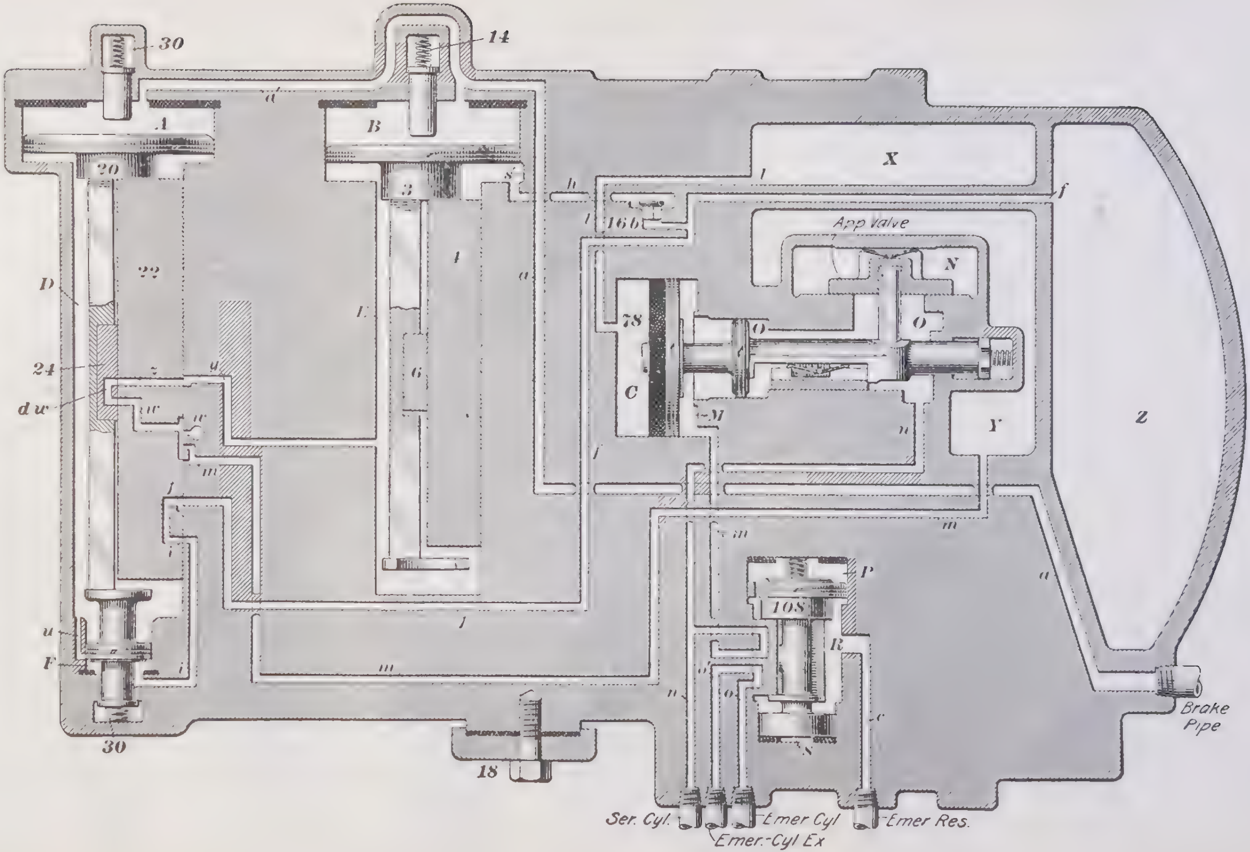

30
14
A
B
X
20
3
App Valve
N
16 b
78
O
C
M
Y
Z
D
22
24
d w
6
u
F
30
18
P
108
R
Brake Pipe
Ser. Cyl.
Emer. Cyl
Emer.-Cyl Ex
Emer Res.

Fig. 36

require a greater differential pressure to move them than is necessary to move the equalizing piston and valves. When the equalizing slide valve *22* has been moved to *preliminary release position*, Fig. 36, it is held momentarily with port z of the slide valve in register with port y of the seat. In this position, the pressure chamber Z is connected with chamber F by port f, ports w and i of the slide valve, and port i of the seat. Chamber-Z pressure in chamber F and the force of the equalizing-piston stop-spring *30* insure the slide valve *22* sufficient time in the preliminary release position to reduce chamber-E pressure below that in the brake pipe by an amount that makes positive the return of piston *3* to release position. Chamber-E air exhausts through port y, port z of the slide valve, cavity $d\,w$ of the graduating valve, and port w of the slide valve, to the reduction-limiting chamber exhaust w.

37. Secondary Release Position.—The reduction of chamber-E pressure as just described results in the release piston moving to release position while the equalizing piston still momentarily remains in position with port z of the slide valve in register with port y of the seat. This position is called the *secondary release position*, and is shown in Fig. 37. With piston *3* in release position, chamber F is connected with the emergency-piston exhaust port Ex by port i and cavity i of the release slide valve. At the same time, the pressure chamber Z is connected to the same port i and chamber F by the port f, ports f and i in the slide valve *22*, and port i. The exhaust of chamber-Z air through port i tends to maintain the pressure in chamber F temporarily while slide valve *4* is increasing the port opening from chamber F to the atmosphere to insure the exhaust from chamber E being held open until after the release piston is in release position. As the moment of the release slide valve toward release position increases the size of the opening of port i, the pressure in chamber F gradually decreases until it is low enough for the differential pressure acting on the piston *20* to start the piston toward release position. This movement of the slide valve *22* gradually restricts and, finally, closes port f, thereby stopping the flow

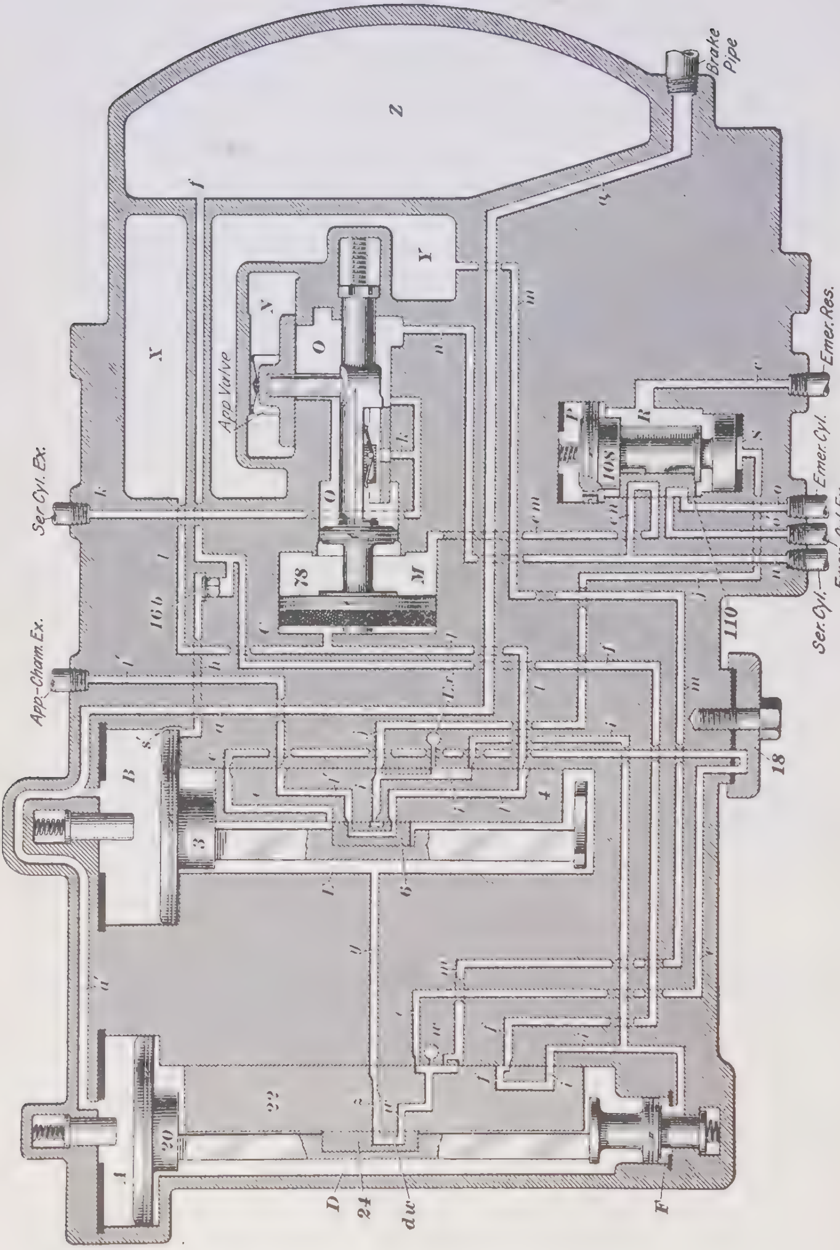

Brake Pipe
Z
X
Y
N
O
App Valve
Ser.Cyl.Ex.
App.-Cham.Ex.
Emer.Res.
Emer.Cyl.
Emer.-Cyl Ex
Ser.Cyl.
78
M
R
S
108
16b
110
18
B
3
4
6
20
22
24
D
dw
F

FIG. 37

of chamber-Z air into port i and chamber F. Chamber-F air then exhausts to the atmosphere, and the equalizing piston is moved to release position and held there.

On referring to Fig. 37, it will be noted that when the slide valve *4* assumes release position, and before the slide valve *22* moves to release position, a second passage is made for the exhaust of chamber-E air to the atmosphere.

In the release position of slide valve *4*, port e of the slide valve registers with port e of the valve seat; therefore, chamber-E air can pass through the ports e, the cavity w of the slide valve and the reduction limiting-chamber exhaust w. This connection, like the connection between ports z and y, is but momentary and is simply a second, or additional, opening from chamber E to the atmosphere.

In regard to the movements described in connection with the two release positions, it should be understood that a brake-pipe pressure of from $1\frac{1}{2}$ to 2 pounds above that in the application chamber X is all that is necessary to move the parts through the momentary successive positions of preliminary and secondary release to release position.

With release slide valve *4* in release position, chamber-C and application-chamber air exhaust to the atmosphere through the ports l, ports l and l' in slide valve *22*, and port l' in the seat, to the application-chamber exhaust. As chamber-C pressure reduces, chamber-O pressure forces piston *78* forwards to release position and exhausts the service-brake cylinder air through port n, chamber O, port k, and the service-cylinder exhaust. The pressure in chamber M exhausts through the ports $e\,m$ and $e\,n$ into port n and thence to the atmosphere.

38. Graduated-Release Position.—With both piston *20* and piston *3* in release position, the control valve is said to be in *graduated-release position* when the direct and graduated release cap *18* is turned, as in Fig. 38, so as to cut in the graduated-release feature. If the cap *18* is turned into the position for direct release, the control valve is then said to be in *direct-release position.* In both cases, the control valve is in release position, but the term *graduated* or *direct* is prefixed to show

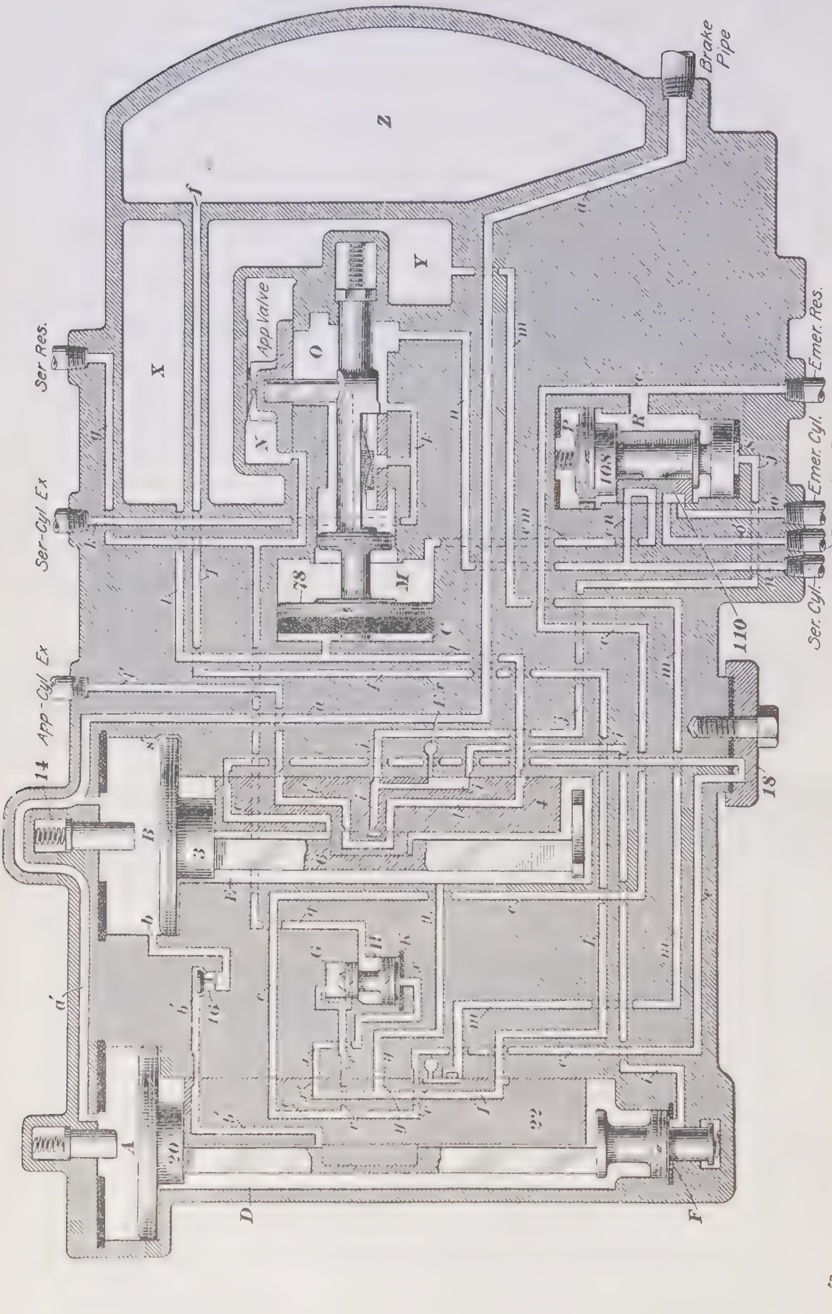

Brake Pipe
Ser Res.
Ser-Cyl Ex
App-Cyl Ex
App Valve
Emer. Res.
Emer. Cyl.
Emer.-Cyl Ex.
Ser. Cyl.

FIG. 38

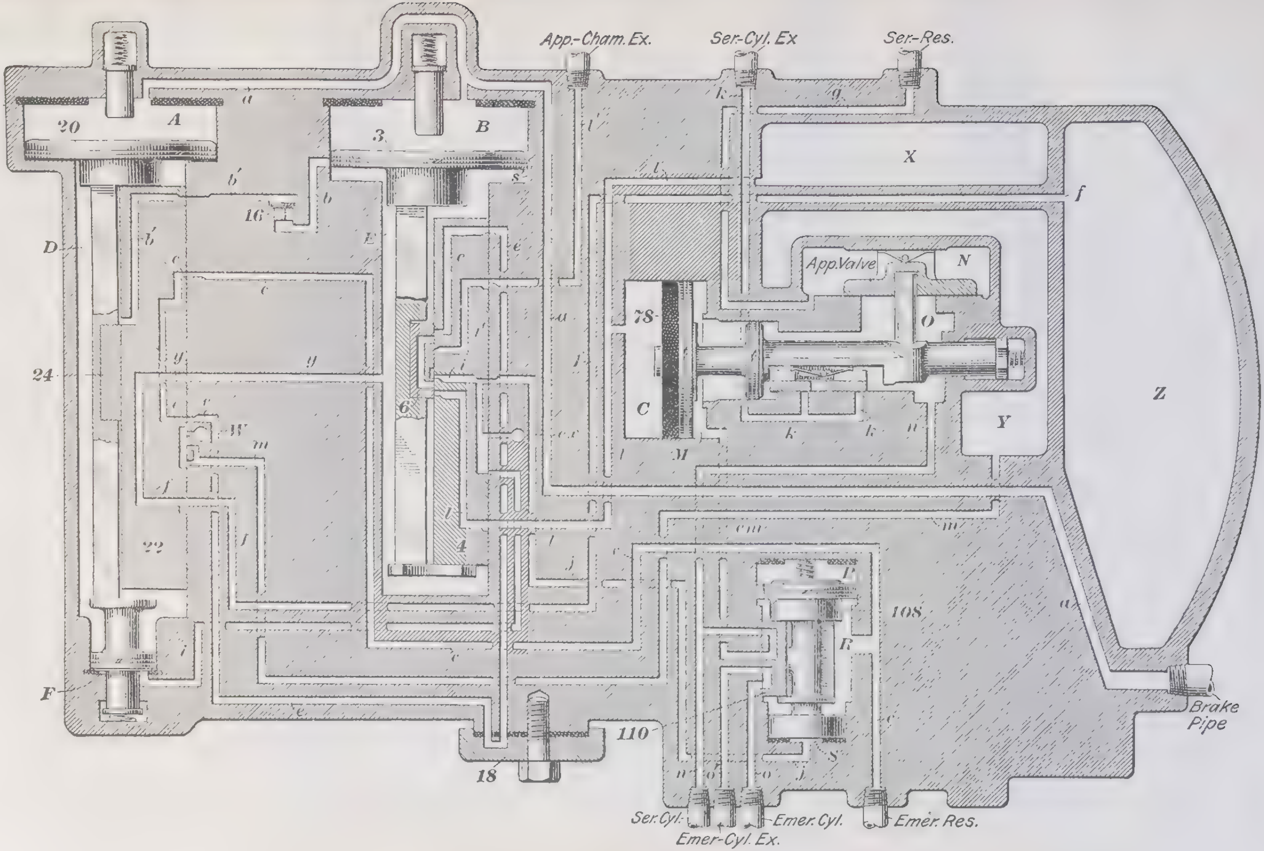

App.-Cham.Ex.
Ser.-Cyl.Ex
Ser.-Res.
20
A
3
B
X
Z
Y
N
O
App.Valve
78
C
M
D
24
F
E
16
6
4
22
W
18
110
108
R
S
Brake Pipe
Ser.Cyl.
Emer-Cyl.Ex.
Emer.Cyl.
Emer.Res.

Fig. 39

whether the cap *18* is turned so as to give a graduated or a direct release of the brake.

From Fig. 38 it will be seen that the application chamber and chamber *C* are open to the atmosphere through ports *l* and *l′* and that the application chamber exhausts. If it were not for the graduated-release feature, the release would be complete. However, it will be noted that the emergency reservoir is connected with chamber *E* through port *c*, ports *c* and *e* of the slide valve *22*, port *e*, through the cap *18*, port *e*, and port *e* of the slide valve *3*, into chamber *E*. Before this connection was made, the chamber-*E* pressure was reduced with the pressure-chamber pressure when the brake application was made. The emergency reservoir, on the other hand, is charged to normal brake-pipe pressure. Therefore, air from the reservoir will flow into chamber *E*, thence through port *y*, ports *y* and *f* of slide valve *22*, and port *f* of the seat, to the pressure chamber *Z*. This pressure tends to increase the pressure in chambers *E* and *Z* at the same time that brake-pipe air is increasing chamber-*B* pressure. If chamber *E*-pressure rises faster than chamber-*B* pressure, the differential pressure thus created on piston *3* will tend to move the piston toward the graduated-release lap position, Fig. 39, and either wholly or partly stop the flow of air from the application chamber to the atmosphere and from the emergency reservoir to chamber *E*. If brake-pipe pressure increases very slowly, the increase in differential pressure may be sufficiently rapid to cause the release piston and graduating valve to graduate the release, as will be explained in connection with Fig. 39. If the rise in brake-pipe pressure is not slow enough to produce this action, the movement of piston *3* toward graduated-release lap position will be sufficient to restrict the flow of air from the emergency reservoir into chamber *E* to an extent sufficient to adjust the rate of rise of pressure in chamber *E* equal to the rate of rise of brake-pipe pressure in chamber *B*. In this case, the release of air from the application chamber and chamber *C* will be correspondingly prolonged.

Whether the brake will be released completely or be graduated off depends on whether chamber-*C* pressure is exhausted

completely at one time or is exhausted by degrees, the pressure being partly exhausted and then held stationary for a time and this repeated several times.

The pressure in the reduction-limiting chamber and in chamber *S* below the emergency slide valve is completely exhausted when a release is made, regardless of whether the release is graduated or direct.

It will be noted from Fig. 38 that chamber *E* (and the pressure chamber) is connected to chamber *K* through the port *y*, ports *y* and *x* of slide valve *22*, and port *x* in the valve seat. Also, it will be noted that emergency-reservoir air can pass to chamber *G* through port *c*, ports *c* and *v* of slide valve *22*, and port *v*. Both these connections are made when slide valve *22* is moved to release position. Whether the service-reservoir charging valve will be operated and thus permit the service reservoir to be recharged will depend on the relative pressures in chambers *G* and *K* and the service reservoir. With the ordinary manipulation of the brake, the service-reservoir charging valve will not be operated, so that no air will pass from the emergency reservoir into the service reservoir; the pressure chamber, however, will be recharged with emergency-reservoir air to within 5 pounds of the pressure in the emergency reservoir. The service-reservoir charging valve then opens and forms connection between the emergency reservoir and the service reservoir through chamber *H*, and the service and emergency reservoirs and the pressure chamber *Z* are all recharged to normal pressure by air from the brake pipe.

In other words, in recharging the brake, first, the pressure chamber alone is recharged to within 5 pounds of emergency-reservoir pressure by air from the emergency reservoir, during which time the brake pipe alone is being recharged from the main-reservoir air supply through the brake valve. Connection is then made between the service reservoir, the emergency reservoir, the pressure chamber, and the brake pipe, and the final stage of the recharging of all these parts is accomplished by air from the main reservoir passing through the brake valve.

As main-reservoir air has the brake pipe alone to recharge during the first stage of the recharge, the rise in brake-pipe

pressure is much more rapid than with the older types of brakes; hence, the release of the brakes throughout the length of the train is much more sure and positive than with the other types.

39. Release Lap Position.—The release of the brake is accomplished by placing the brake valve in release position so as to raise brake-pipe pressure, recharge the brake pipe, and move the pistons *20* and *3* to release position. If the handle of the brake valve is left in release position, the brake will release in one continuous exhaust of brake-cylinder air without any graduations of brake-cylinder pressure. On the other hand, if the brake valve is moved to release position for a time and is then moved to lap, only part of the brake-cylinder pressure will be exhausted, and by repeating the movement of the brake valve from release to lap positions the brake can be graduated off. In graduating the brake off, this is what occurs: While the brake pipe is recharging through the brake valve, the pressure chamber and chamber *E* are recharging with air from the emergency reservoir. If, now, the brake-valve handle is moved to lap position when the brake pipe is only partly recharged, the continued flow of air from the emergency reservoir with chamber *E* will raise the pressure in chamber *E* above that in chamber *B*, which is now stationary, and cause the release piston *3* to move to *graduated-release lap position*, Fig. 39. In this position, the shoulder of the stem of piston *3* is against the slide valve *4*, the flow of air into chamber *E* ceases, and the graduating valve blanks port *l* and stops the exhaust of air from chamber *C* and the application chamber. This holds chamber-*C* pressure constant, and the application portion maintains brake-cylinder pressure constant and equal to chamber-*C* pressure. If the brake valve is again moved to release position and then back to lap position again, piston *3* will be moved to release position and then back to release lap position, and this action will be repeated. The gradual release of the brake can be continued until the emergency reservoir and the pressure chamber equalize at a pressure about 5 pounds below normal brake-pipe pressure.

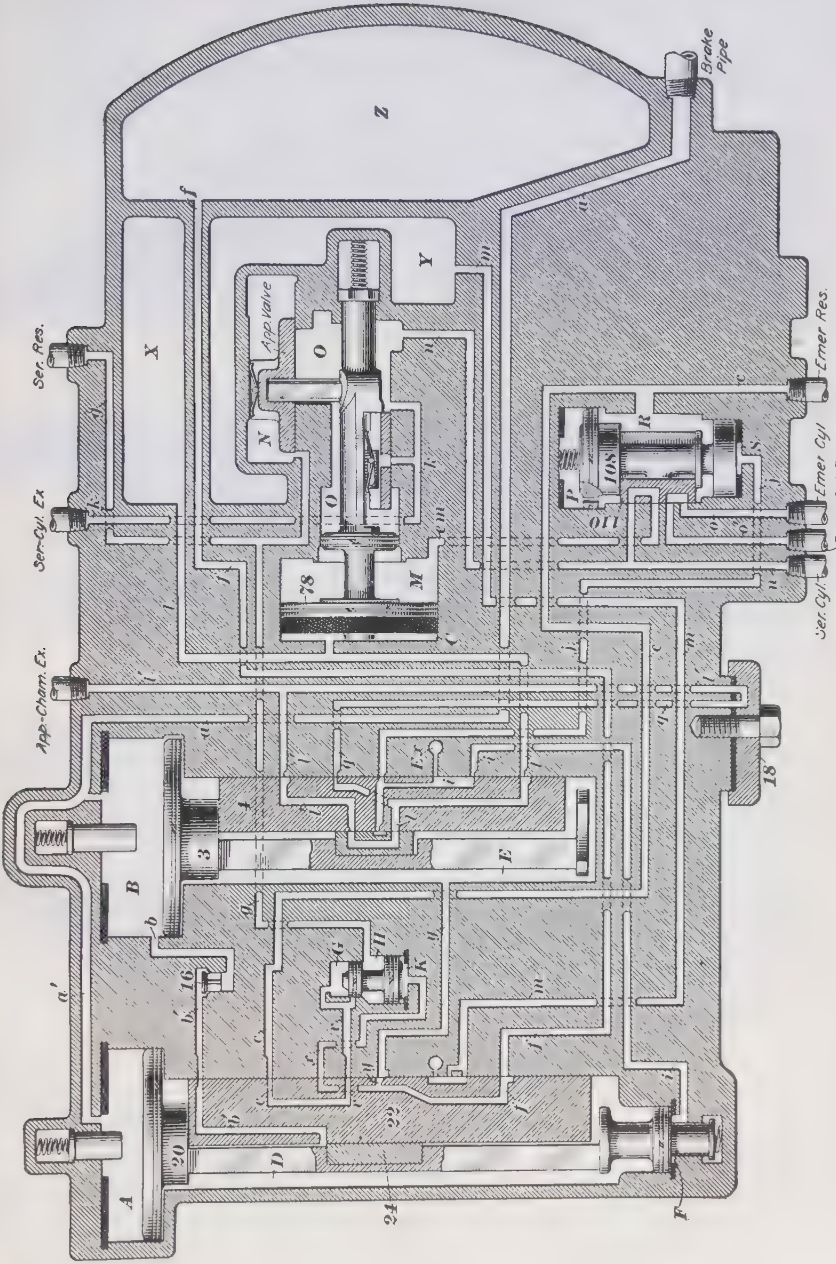

Ser. Res.
Ser.-Cyl. Ex
App.-Cham. Ex.
App. Valve
Brake Pipe
Emer Res.
Emer Cyl
Emer-Cyl Ex.
Ser. Cyl.

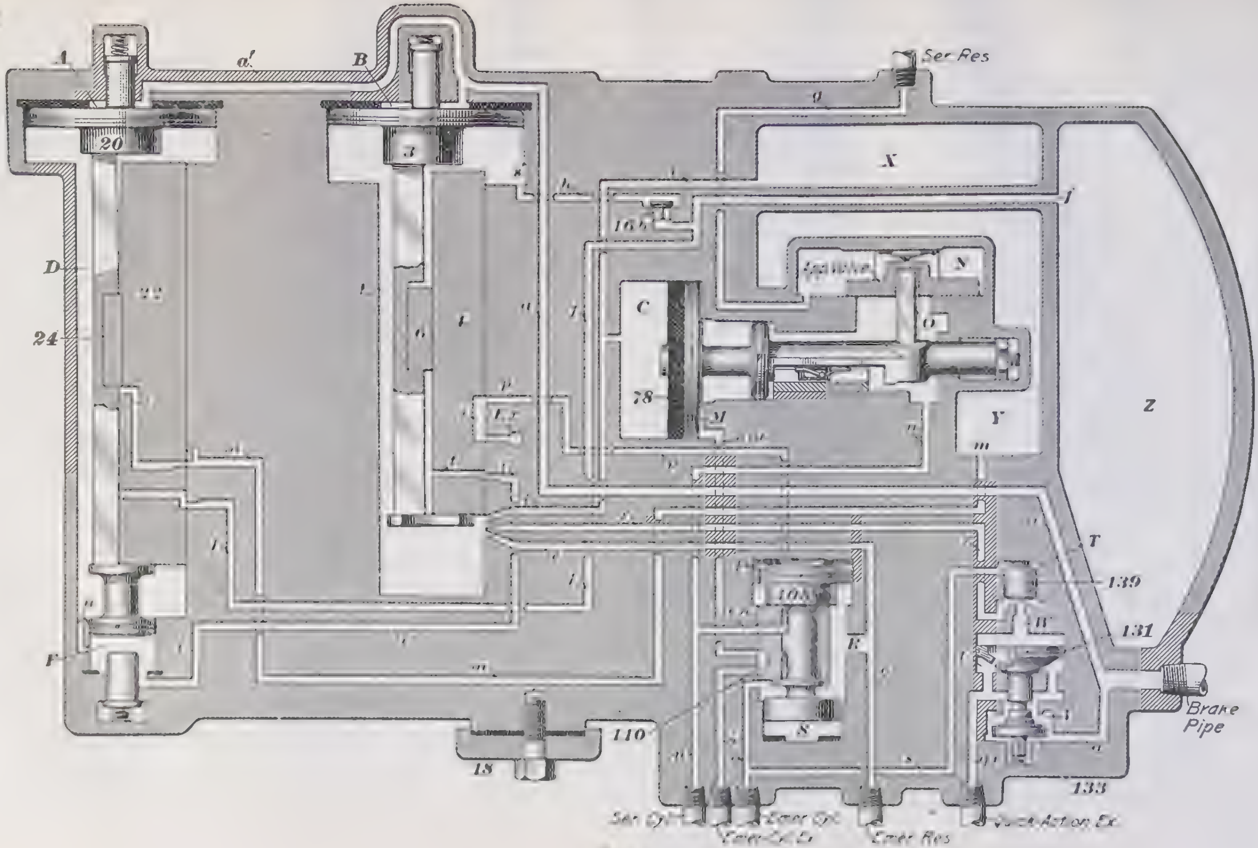
FIG. 40

40. Release Position—Charging the Pressure Chamber and the Emergency and Service Reservoirs.—As already explained, the recharging of the pressure chamber to within 5 pounds of brake-pipe pressure is accomplished with emergency-reservoir air. By the time this is accomplished the service-brake cylinder is entirely released, and the final stage of recharging the pressure chamber and the emergency and service reservoirs is accomplished by the use of air from the brake pipe, as described in connection with Fig. 28.

41. Direct-Release and Charging Position.—The direct-release position, Fig. 40, is the same as the graduated-release position, Fig. 38, except that the direct and graduated release cap *18*, Fig. 40, is turned to the position for the direct release of the brake. With cap *18* in this position, the brake cannot be graduated off.

Changing the position of cap *18* cuts off the connection between the emergency reservoir and the application chamber and chamber *E*. During direct release, therefore, the chambers *E* and *Z* are recharged from the brake pipe through the feed groove *s′* past the piston *3*. There is direct connection between chamber *E* and chamber *Z* through port *y*, ports *y* and *f* of slide valve *22*, and port *f* of the valve seat. As chamber *E* charges from chamber *B*, it follows that chamber-*E* pressure cannot increase above chamber-*B* pressure; therefore, piston *3* cannot be moved to graduated lap position and the brake cannot be graduated off.

On referring to Fig. 40, it will be observed that the chambers *C* and *X* are open to the atmosphere through port *l*, ports *l* and *q* of slide valve *4*, port *q*, cap *18*, port *l′*, and the application-chamber exhaust. This affords an exhaust outlet for chamber *X* which cannot be closed as long as the release slide valve *4* remains in release position. There is a second path from the application chamber to the exhaust; it leads through port *l*, port *l* in slide valve *4*, cavity *d w* in the graduating valve *6*, ports *l′* in the slide valve and seat, and the application-chamber exhaust. It is possible, however, for this path to be partly restricted or, perhaps, entirely closed by the piston *3* moving



A
a'
B
20
D
24
F
Ser Res
X
Z
Y
C
78
M
N
O
165
Ex
T
139
131
133
110
18
S
108
R
E
Brake Pipe
Ser Cyl
Emer Cyl
Emer Cyl Ex
Emer Res
Quick Action Ex

Fig. 41

the graduating valve *6* so as to partly or wholly close port *l* in the slide valve *4*. The first path mentioned, however, insures direct connection to the atmosphere.

It will thus be seen that there are two outlets from the application chamber to the exhaust in direct release position, while there is only one outlet when cap *18* is turned so as to give graduated release. The capacity of the release port, therefore, is greater for direct release than for graduated release, and thus gives a more rapid release with the direct-release adjustment, which is desirable.

42. Quick-Action Valve Venting.—Either a brake-pipe reduction that is too fast or a reduction so heavy that it reduces brake-pipe pressure below the pressure of equalization of the pressure chamber and the reduction-limiting chambers will produce a differential pressure on pistons *3* and *20* that will move them to their emergency positions, Fig. 41.

With the slide valve *4* in emergency position, emergency-reservoir air passes through port *c* direct into chamber *E* and thence through port *r* to the space below the quick-action closing valve *139*. Chamber *T*, above valve *139*, is connected by port *s* with port *o*, and the emergency brake cylinder, which is connected to the atmosphere through port *o*, the cavity in the emergency slide valve, port *o′*, and the emergency-cylinder exhaust; consequently, the quick-action closing valve *139* is raised from its seat and emergency-reservoir air flows into chamber *W* above the quick-action piston *131*. This forces piston *131* down and opens the quick-action valve *133* against the brake-pipe pressure in chamber *V*, which vents brake-pipe air to the atmosphere through chamber *V*, port *q x*, and the quick action exhaust, thereby producing a local drop in brake-pipe pressure that transmits the quick-action serially throughout the train.

Air from the emergency cylinder, after flowing to chamber *E*, also passes through port *l* direct to chamber *C* and the application chamber. This forces piston *78* back into application position, which closes the exhaust ports *k* and opens the application-valve port wide, thus allowing the service reservoir

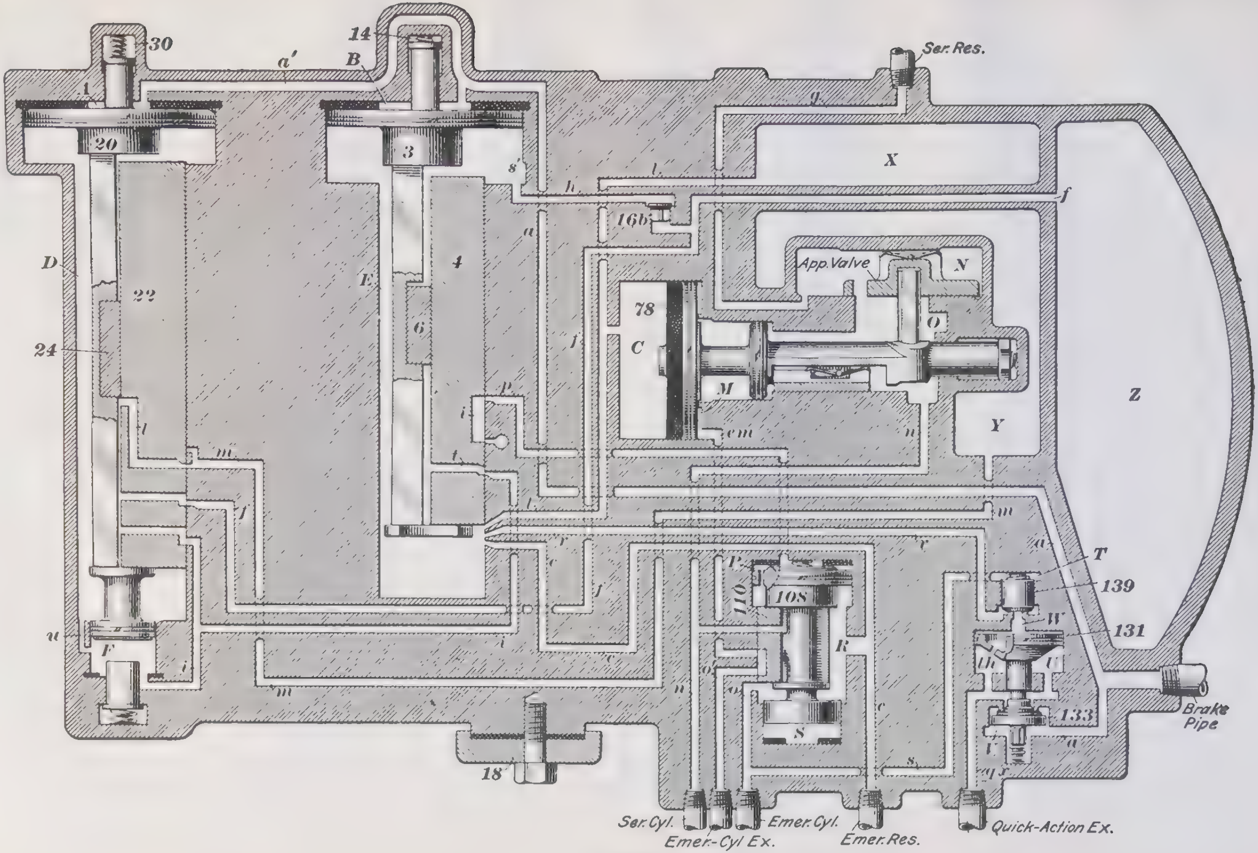

Ser. Res.
App. Valve
Brake Pipe
Ser. Cyl.
Emer.-Cyl Ex.
Emer. Cyl.
Emer. Res.
Quick-Action Ex.
30
14
20
3
22
24
4
6
78
16b
108
110
139
131
133
18
X
Y
Z
N
O
M
C
T
W
R
S
D
E
F
B

FIG. 42

and the service brake cylinder to equalize through port *g*, chambers *N* and *O*, and port *n*.

The same movement of the slide valve *4* to emergency position also opens chamber *P*, above the large emergency piston *108*, to the atmosphere through port *p* and cavity *i* in slide valve *4*. Emergency-reservoir pressure in chamber *R* then forces the emergency piston *108* and the slide valve *110* to their emergency positions, thereby connecting the emergency brake cylinder with the emergency reservoir through port *c*, chamber *R*, and port *o* and allowing the pressure to equalize in the cylinder and reservoir; also, chamber *R* is connected to the service cylinder through port *e n* and port *n*, thus allowing all the service and emergency brake cylinders and reservoirs to equalize with one another.

Chamber *M*, behind piston *78*, is connected to the atmosphere through ports *e m*, the cavity in the emergency slide valve, port o', and the emergency cylinder exhaust. This is done to assist the pressure in chamber *C* in making the piston *78* move quickly and positively to emergency position, as shown in Fig. 41.

It will be noted that in emergency position the pressure chamber *Z* is connected to chambers *D* and *E*, and chamber *D* is connected to chamber *Y*. The purpose of this is to equalize the pressure in all the chambers and reservoirs and to insure sufficient pressure on all the slide valves and graduating valves to hold them to their seats.

43. Quick-Action Valve Closed.—The closing of the quick-action valve *133*, Fig. 42, after making a local vent to the atmosphere to transmit quick action serially throughout the train, is accomplished as follows: As soon as quick action occurs, emergency-cylinder pressure and, therefore, chamber-*T* pressure, begins to rise, while the pressure in chamber *W* and the emergency reservoir begins to fall. When the pressures in chambers *T* and *W* become nearly equal, the spring of valve *139* closes the valve and stops the flow of air into chamber *W*. The air thus trapped in chamber *W* escapes through the leakage hole *l h* in the piston *131* to the atmosphere through

port *q x* and the quick-action exhaust. This balances the pressure on the two faces of piston *131*, and the spring of valve *133* and brake-pipe pressure closes the valve *133* and stops the escape of brake-pipe air to the atmosphere. If the brake-pipe pressure is entirely depleted, the spring of valve *133* will close the valve and thus insure against a loss of brake-pipe air when a release is made immediately after the quick-action application.

OPERATING THE BRAKE

44. Handling the Brake.—In handling a train equipped with P C equipment, the brake should be manipulated in the same manner as the brake of a train equipped with quick-action triples. However, it should be borne in mind that an emergency application will result if the brake-pipe reduction reduces brake-pipe pressure below 60 pounds from a 110-pound brake-pipe pressure, or below 35 pounds from a 70-pound brake-pipe pressure.

45. Cutting Out a Brake.—Should it become necessary to cut out a brake, close the cut-out cock in the branch pipe that leads from the brake pipe to the control valve, and bleed all the pressure out of both the service reservoir and the emergency reservoir.

Should it be necessary to bleed the reservoirs when the engine is detached and air is not connected to the brake, first empty the brake pipe and then bleed both the service and the emergency reservoirs.

46. To Determine When a Brake Is Set.—By referring to Figs. 2 and 3, it will be seen that there are two cylinder levers for both the service-brake cylinder and the emergency-brake cylinder. Each of the two truck pull rods has a cylinder lever from each cylinder attached to it; thus, whenever the service-brake cylinder operates and moves the service-cylinder lever, it also moves the push-rod end of the emergency-cylinder lever the same distance as the push-rod end of the service-cylinder lever. To allow for this movement of the

cylinder lever without the brake piston moving, the cylinder-lever connection at the push-rod end of the brake cylinder is made in the form of a slotted crosshead, as shown in Figs. 2 and 3. When, therefore, the service brake is set, the push-rod end of the emergency-cylinder lever will move out, but the emergency-brake piston will not move. Therefore, the fact that the emergency-cylinder crosshead is in release position does not indicate that the brake is released. To determine whether or not the brake is set, the service-cylinder push rod should be observed; if it is out, the brake is set.

47. Adjusting the Slack Adjuster.—When it becomes necessary to adjust the automatic slack adjuster, care must be taken to have the crossheads of the two adjusters at the same distance from their respective cylinder heads when the adjustment is finally made, so as to have the same piston travel for the two cylinders in emergency applications.

DEFECTS AND CARE OF EQUIPMENT

BLOWS

48. Blow at Quick-Action Exhaust.—A continuous blow occurring at the quick-action exhaust, Fig. 7 (*a*), will be due to the quick-action valve being held off its seat by dirt or to the valve seat being defective. If the trouble is caused by dirt on the seat of the valve, it can be remedied by making an emergency application and then releasing the brake. If the blow continues, the quick-action portion (marked *D*, Fig. 7) will have to be either replaced or repaired.

49. Blow at Application-Chamber Exhaust.—In the event of a blow occurring at the application-chamber exhaust, Fig. 7 (*a*), with the brakes either applied or released, make a 15-pound service reduction and bleed both the service and emergency reservoirs. If the blow continues, it indicates that the equalizing portion (marked *A*, Fig. 7) is defective and must be either replaced or repaired.

50. Blow at Reduction-Limiting-Chamber Exhaust. Should a blow occur at the reduction-limiting-chamber exhaust port, Fig. 7 (*a*) and (*b*), make a 30-pound reduction and lap the brake valve. If the blow ceases, the application portion (marked *C*, Fig. 7) is defective, in which case it should be replaced or repaired. If the blow does not cease, the trouble is in the equalizing portion (marked *A*, Fig. 7).

51. Hard Blow at Service-Cylinder Exhaust.—Should there be a hard blow at the service-brake-cylinder exhaust [Fig. 7 (*a*)] with the brake either applied or released, the application portion (marked *C*, Fig. 7) is defective and it should be replaced or repaired.

52. Hard Blow at Emergency-Cylinder Exhaust. If a blow occurs at the emergency-cylinder exhaust port, Fig. 7 (*c*), with the brake either applied or released, it indicates that there is a defect in the emergency portion (marked *E*, Fig. 7) and that this portion should be either replaced or repaired.

53. Blow at Emergency-Piston Exhaust.—In the event of a blow occurring at the emergency-piston exhaust, Fig. 7 (*c*), make a 15-pound service brake-pipe reduction and lap the brake valve. If this causes the blow to cease, the emergency portion (marked *E*, Fig. 7) is defective and should be replaced or repaired. If the blow continues, the equalizing portion (marked *A*, Fig. 7) is defective and this portion should be either replaced or repaired.

54. Removing and Replacing Control-Valve Portions.—When removing the application portion *C*, Fig. 7, the quick-action portion *D*, or the emergency portion *E*, care should be taken to leave the gasket on the reservoir. When removing the equalizing portion *A*, Fig. 7, the gasket should be left on the flange of the application portion, except when the application portion is shipped to or from points where triple valves are cared for.

In applying the different portions of the control valve, the gasket should be examined carefully to make sure that

there are no defects that will prevent leakage between the parts of the gasket or that will block or restrict the ports in the flanges of the control valve.

LUBRICATING THE CONTROL VALVE

55. Equalizing Portion.—The equalizing portions of the control valve should be lubricated with a high grade of dry graphite (not flake graphite) of the highest obtainable fineness and purity. Oil should not be used for this purpose. A free use of oil should be made in "rubbing in" the bearing surfaces of the equalizing portion, but all oil, gum, or grease should be thoroughly removed from the slide valves and seats before lubricating them, as follows: Rub graphite on the face of the slide valves and their seats, on the face of the graduating valves and their seats, and on the upper portions of the bushings where the slide-valve springs bear. The graphite should be applied in such a way as to fill in the pores of the brass and leave a very thin, light coating on the seats. After lubricating the parts, care should be taken not to touch them with the hands, as moisture tends to remove the thin coating of graphite and thus destroy the lubrication.

The graphite is best applied with a stick about 8 inches long, to one end of which is glued a small pad of chamois skin. The skin on the end of the stick is dipped in the graphite, and the graphite is rubbed on the surfaces to be lubricated. A few light blows of the chamois on the valve seats will leave sufficient loose graphite on them.

After the pistons and slide valves are replaced in the equalizing portion, they should be moved to release position so that a little oil may be rubbed on the piston bushings; the pistons should then be moved back and forth several times to make sure that the oil is evenly distributed on the bushing. Only a thin coating of oil should be used, and it should be well rubbed in so that there will be no free oil left on the parts after they have been oiled.

56. Application Portion.—The application valve and seat and the exhaust valve and seat of the application portion

of the control valve should first be cleaned; next, they should be rubbed in with oil, which should be thoroughly removed; and, finally, they should be lubricated with graphite in a manner similar to that just explained for lubricating the slide valve and seats of the equalizing portion. During the time that the piston is removed the cylinder should be cleaned and the walls lightly lubricated with a good grade of valve oil. The piston and piston ring should be cleaned and the ring lubricated with a little valve oil of good quality, a few drops of the oil being applied to the packing leather.

57. Emergency Portion.—The emergency portion of the control valve should be lubricated in the following manner: First, remove the parts and thoroughly clean the bearing surfaces; next, rub in the parts, using oil for the purpose, and thoroughly clean off all oil and grease; then, lubricate the bearing surfaces with graphite in the manner already explained. Remove the top cover and take out the loose-fitting cylinder bushing. Lubricate the large piston with a few drops of a good grade of triple-valve oil and apply the slide valve to the portion. Lubricate the stop-bushing for the small emergency bushing, applying a few drops of oil to its inner surface. Then replace the bushing and bolt on the top cover. Move the slide valve to release position and apply a few drops of good triple-valve oil to the walls of the large cylinder bushing, and then move the piston back and forth several times to distribute the oil properly. Finally, replace the large cover of the emergency portion.

58. Quick-Action Portion.—Only the quick-action closing-valve piston *131*, Fig. 26, and the cylinder bushing of the quick-action portion require lubrication. Just a few drops of oil are sufficient; the piston, however, should be worked back and forth several times to distribute the oil properly and to make sure that it moves as freely as it should.

PM AND LN PASSENGER BRAKE EQUIPMENTS

THE PM PASSENGER BRAKE EQUIPMENT

DESCRIPTION AND OPERATION

1. Development of the Passenger-Car Brake.—For some time after the introduction of the air brake, the same brake apparatus was used on both freight and passenger cars; that is, the brake equipment consisted of a triple valve, an auxiliary reservoir, and a brake cylinder. It became apparent, as improvements were made in the construction of rolling stock and in train operation, that a brake suitable for freight cars would not be suitable for passenger cars. The reason why the same brake could not be used on both kinds of cars was that the conditions which govern the control of freight and passenger trains are altogether different. The conditions which must be considered when designing a brake for passenger trains, are the speed of such trains, their weight, and the frequency at which the trains are run. The design of a suitable brake for freight cars requires the consideration of two factors: the length of such trains and the difference between the weight of the cars when they are loaded and when they are empty. It will, therefore, be evident why the brake equipments for passenger and freight cars have been developed along different lines.

The brake equipment, which was used on passenger cars,

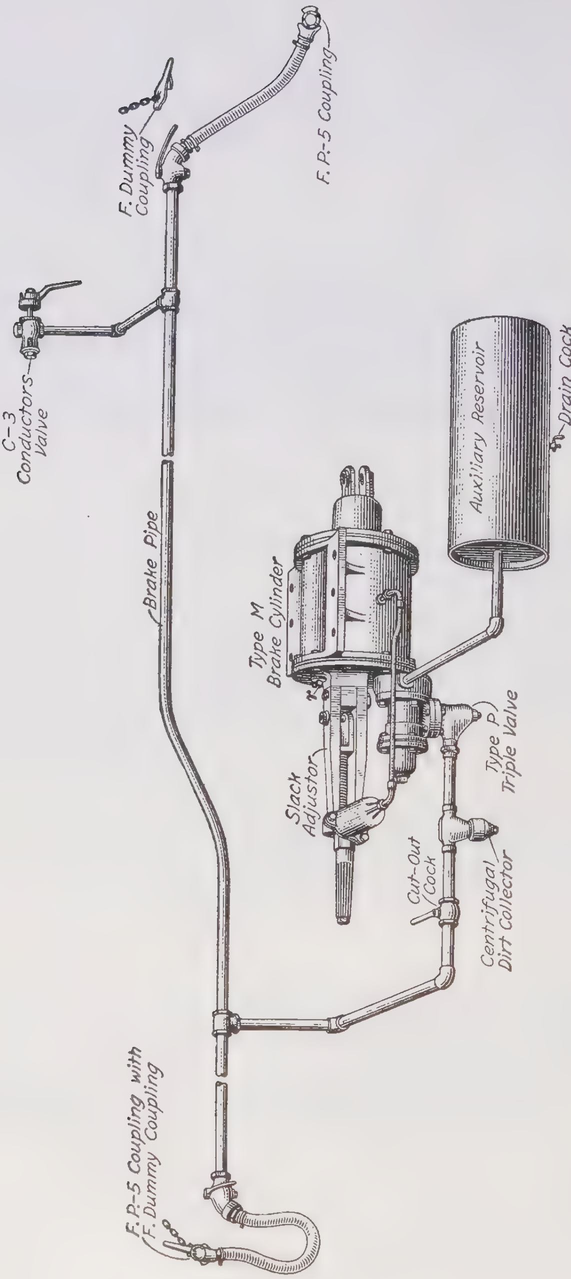

F. Dummy Coupling
F. P.-5 Coupling
C-3 Conductors Valve
Brake Pipe
Auxiliary Reservoir
Drain Cock
Type M Brake Cylinder
Slack Adjustor
Type P Triple Valve
Cut-Out Cock
Centrifugal Dirt Collector
F. P.-5 Coupling with F. Dummy Coupling

FIG. 1

underwent changes as conditions arose which made trains more difficult to control. Therefore, various brake equipments were designed for passenger cars as the construction of these cars was changed from all wood to all steel.

The first brake equipment designed solely for passenger cars was known as the *high-speed brake;* this equipment is now called the *PM equipment.* It is still in use on the older type of passenger cars and proved to be a satisfactory brake for passenger trains for some time after it was developed, but conditions which the brake was designed to meet changed to such an extent that it became necessary to design a brake of greater efficiency. When the PM equipment was introduced, the passenger cars were of all-wood construction, and were, therefore, comparatively light. As the locomotives became more powerful, the wooden cars on modern passenger trains were displaced by cars constructed of both steel and wood, and finally the all-steel car was introduced. The great weight of trains which consisted of part-steel or all-steel equipment, and the high speed at which these trains were run, made it necessary to provide a means whereby they could be controlled as safely as were the lighter trains of the past. The brake equipments which followed the introduction of the modern passenger car are known as the LN equipment, the PC equipment, and the UC equipment, these equipments being put out in the order in which they are named.

2. Arrangement of the PM Equipment.—The arrangement of the PM passenger brake equipment is shown in Fig. 1. The parts of the equipment consist of a triple valve, an auxiliary reservoir, a brake cylinder, a high-speed reducing valve (not shown but which is piped to the brake cylinder at *r*), and the piping and hose. The triple valve is bolted to the pressure head of the brake cylinder and the auxiliary reservoir is also connected by a pipe to the brake-cylinder head. A type P triple valve and a type M brake cylinder is used with this equipment, and it is from these types of apparatus that the equipment obtains its name. This brake equipment was the same as the brake equipment which it superseded, with the

exception of the high-speed reducing valve. A brake-pipe pressure of 110 pounds instead of the usual pressure of 70 pounds was used with the PM equipment.

3. Principles on Which PM Equipment Is Based. The principles on which the design of the PM equipment are based, were deduced from the Westinghouse-Galton tests in England in 1878. These tests showed that the friction between the brake shoe and the wheel is considerably less when the wheels are revolving rapidly than when they revolve slowly. Therefore, the brake shoes may be applied to the wheels with greater pressure when the sped is high without danger of sliding the wheels than when the speed is low. The brake equipment was then designed so that in an emergency application the brake-cylinder pressure and, therefore, the brake-shoe pressure, or the braking force,* would be greater at the beginning than at the end of the stop. The design of the brake would then permit of the maximum braking force with the least danger of the wheels sliding.

When an emergency application of the brakes was made, the initial braking force was 125 per cent., which decreased to the normal braking force of 90 per cent. by the time the train had stopped. The variation in the braking force while the train was stopping was brought about by the operation of the high-speed reducing valve.

4. Advantages of High Brake-Pipe Pressure.—A brake-pipe pressure of 110 pounds as used with the PM equipment, has several advantages over a brake-pipe pressure of 70 pounds. When an emergency application is made, the brake-cylinder pressure is 85 pounds instead of 60 pounds. The brake-cylinder pressure obtained from a full-service application, is limited to 60 pounds by the reducing valve, and this pressure is 10 pounds higher than the pressure of equalization with a brake-pipe pressure of 70 pounds. The brakes can be applied three times and a brake-cylinder pressure of 50 pounds

*Braking force refers to the pressure, with which the brake-shoes are forced against the wheels. A braking force of 125 per cent. means that the brake-shoe pressure is 125 per cent. of the weight of the car.

obtained each time before it is necessary to recharge. Thus, a reduction of 20 pounds from 110 pounds brake-pipe pressure will give a brake-cylinder pressure of 50 pounds. If the brakes are now released, and no attempt is made to recharge, another reduction of 20 pounds will reduce the brake-pipe pressure to 70 pounds and will give a brake-cylinder pressure of 50 pounds. Another reduction of 20 pounds in brake-pipe pressure will give a brake-cylinder pressure of 50 pounds, and will leave the auxiliary-reservoir and the brake-pipe pressures equal at 50 pounds. It will now be necessary to recharge. It will be noted that a 20-pound reduction from a high brake-pipe pressure does

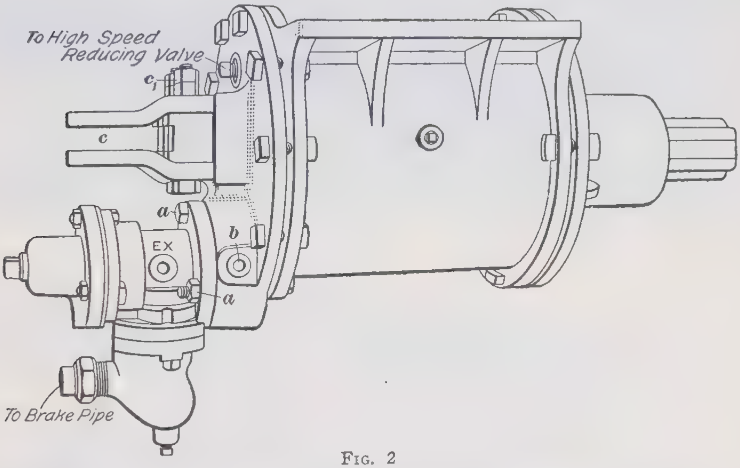


Fig. 2

not give any higher pressure in the brake cylinder than a reduction from a lower brake-pipe pressure.

DESCRIPTION OF THE PARTS

5. **Triple Valve and Brake Cylinder.**—In Fig. 2 is shown an exterior view of the triple valve and the brake cylinder. Three studs and nuts *a*, two of which are shown, are used to secure the triple valve to the brake-cylinder head. The auxiliary-reservoir pipe is connected to the brake-cylinder head at *b* and the triple-valve exhaust port is marked EX. The brake pipe is connected to the triple valve at the

point shown. The lever bracket for the dead-cylinder lever is marked c, and the lever-bracket bolt and nut, of which there are two, is marked c_1. The lever bracket is removed when

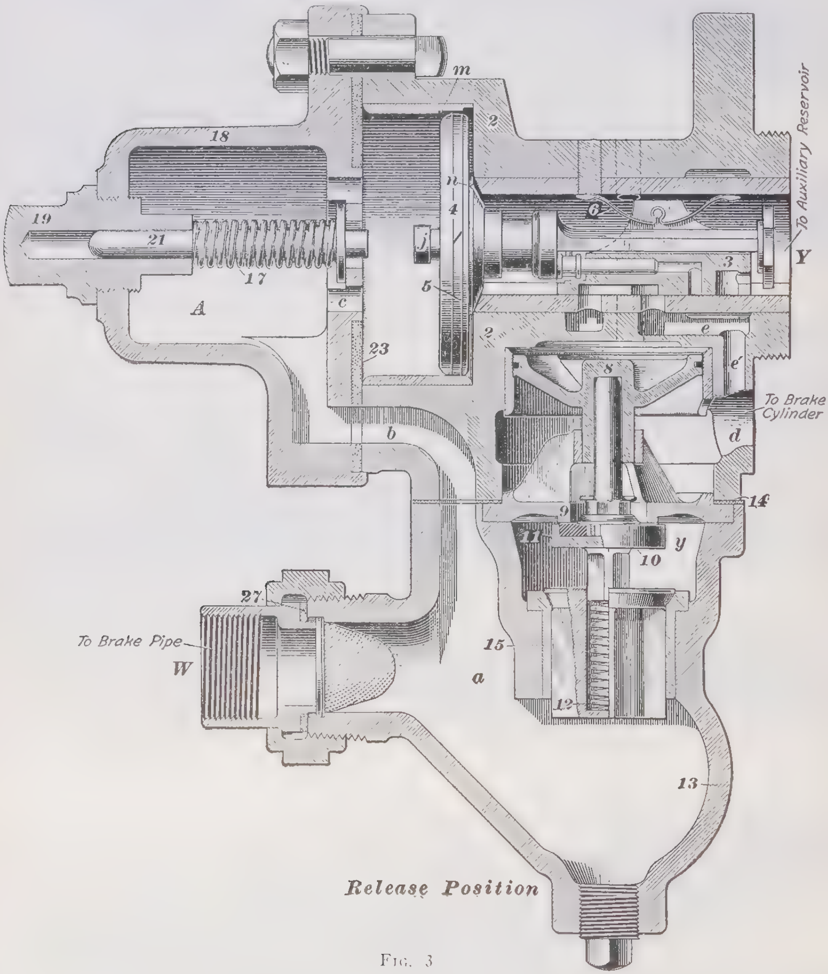


FIG. 3

the automatic slack adjuster is used. The nuts and bolts c_1 are then used to secure the adjuster to the brake cylinder.

6. The Type P Triple Valve.—The type P triple valve, which is used with the PM equipment, is shown in Fig. 3.

This valve is similar in appearance to the type H freight triple valve, and the parts of each have the same reference numbers. However, unlike the H triple valve, the emergency piston *8* of the P triple valve has a packing ring. This insures that the emergency piston will remain unseated longer when an emergency application is made than when no ring is used.

7. Type M Brake Cylinder.—A sectional view of the type M brake cylinder is shown in Fig. 4. It will be necessary to consider only the cylinder head to which the triple valve is attached, as in other respects the brake cylinder does not differ from the others which have already been described. A pas-

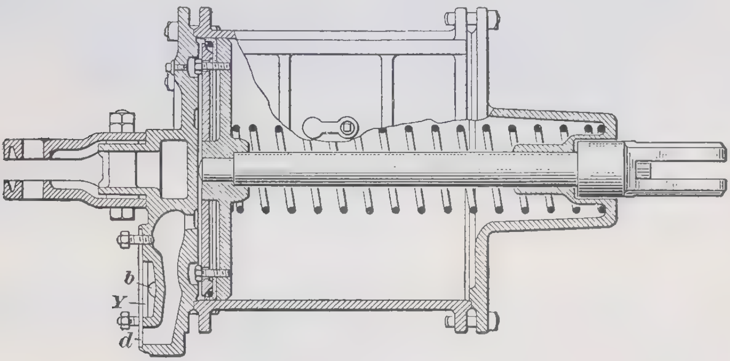


FIG. 4

sage *d* leads from the outer face of the cylinder head into the brake cylinder. The outer end of passage *d* connects with port *d* in the triple valve, Fig. 3, when the valve is bolted to the brake-cylinder head. The pipe from the auxiliary reservoir is connected to the cylinder head at *b*. Passage *b* leads through the brake-cylinder head to an opening *Y*. The opening *Y* which is in the triple valve, Fig. 3, comes opposite the opening *Y* in the cylinder head when the triple valve is bolted to it.

8. Brake-Cylinder Head.—The brake-cylinder head is shown in Fig. 5. The opening *Y* in the triple valve, Fig. 3, comes opposite *y* in the head. The auxiliary-reservoir passage *b* connects to the opening *y* Fig. 5. A similar passage

leads into y from the opposite side of the cylinder head. The auxiliary-reservoir pipe may then be connected to either side of the brake-cylinder head, the passage which is not used being closed by a plug.

The passage d, which connects the triple valve to the brake cylinder, leads through the part d_1, of the brake-cylinder head, to the other side of this head. The pipe from the high-speed reducing valve is connected to the cylinder head at r.

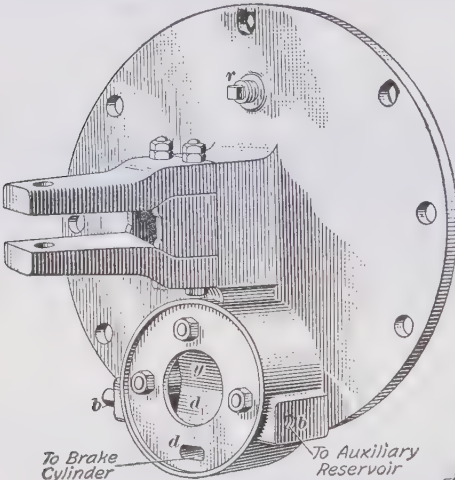


Fig. 5

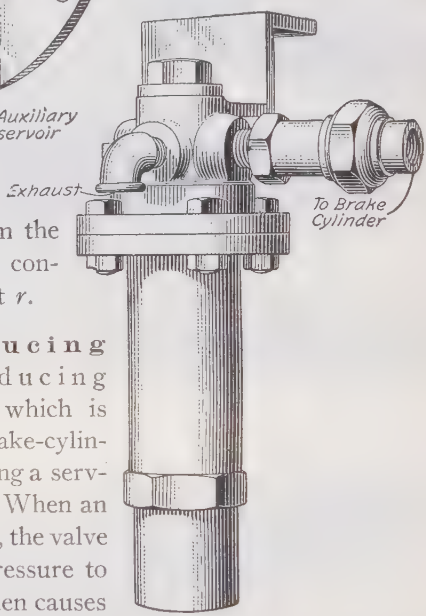


Fig. 6

9. High-Speed Reducing Valve.—The high-speed reducing valve, an exterior view of which is shown in Fig. 6, limits the brake-cylinder pressure to 60 pounds during a service application of the brakes. When an emergency application is made, the valve permits the brake-cylinder pressure to increase to 85 pounds, and it then causes a gradual reduction of the pressure to 60 pounds. The reduction of pressure from 85 pounds occurs slowly at first and then becomes more rapid so as to proportion the blow-down of pressure to the reduction in speed, and thus prevent the wheels from sliding.

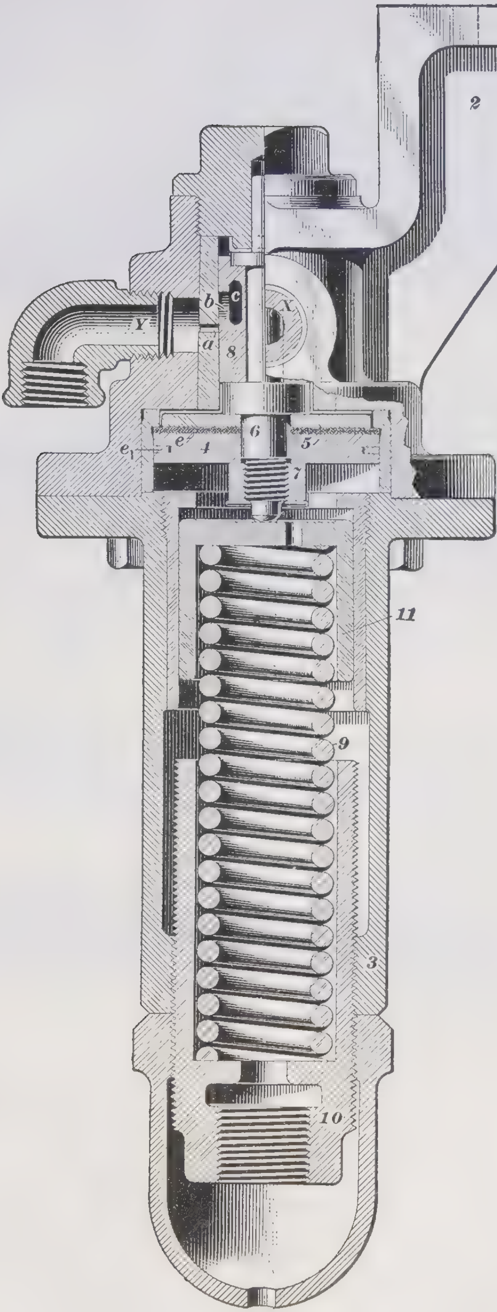


Fig. 7

10. Names of Parts.—A sectional view of the high-speed reducing valve is shown in Fig. 7. The names of the principal parts are as follows: *2,* valve body; *3,* spring box; *4,* piston with seat e and packing ring e_1; *5,* piston disk; *6,* piston stem; *7,* piston stem nut; *8,* slide valve; *9,* regulating spring which is set for 60 pounds; *10,* regulating nut; *11,* spring abutment.

The brake cylinder is piped to port X, and the air from the brake cylinder fills the space above the piston *4* when the brakes are applied. Port a leads through a slide-valve seat to the exhaust port Y.

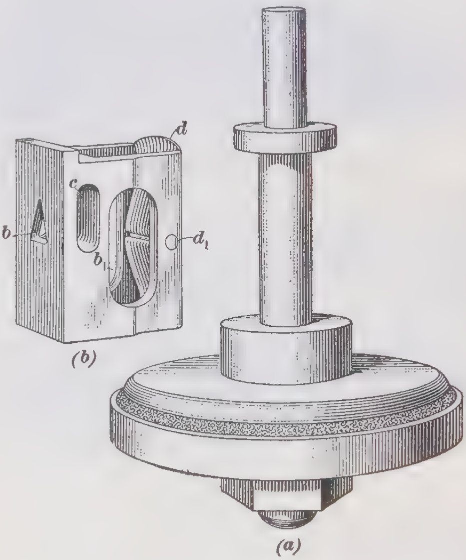
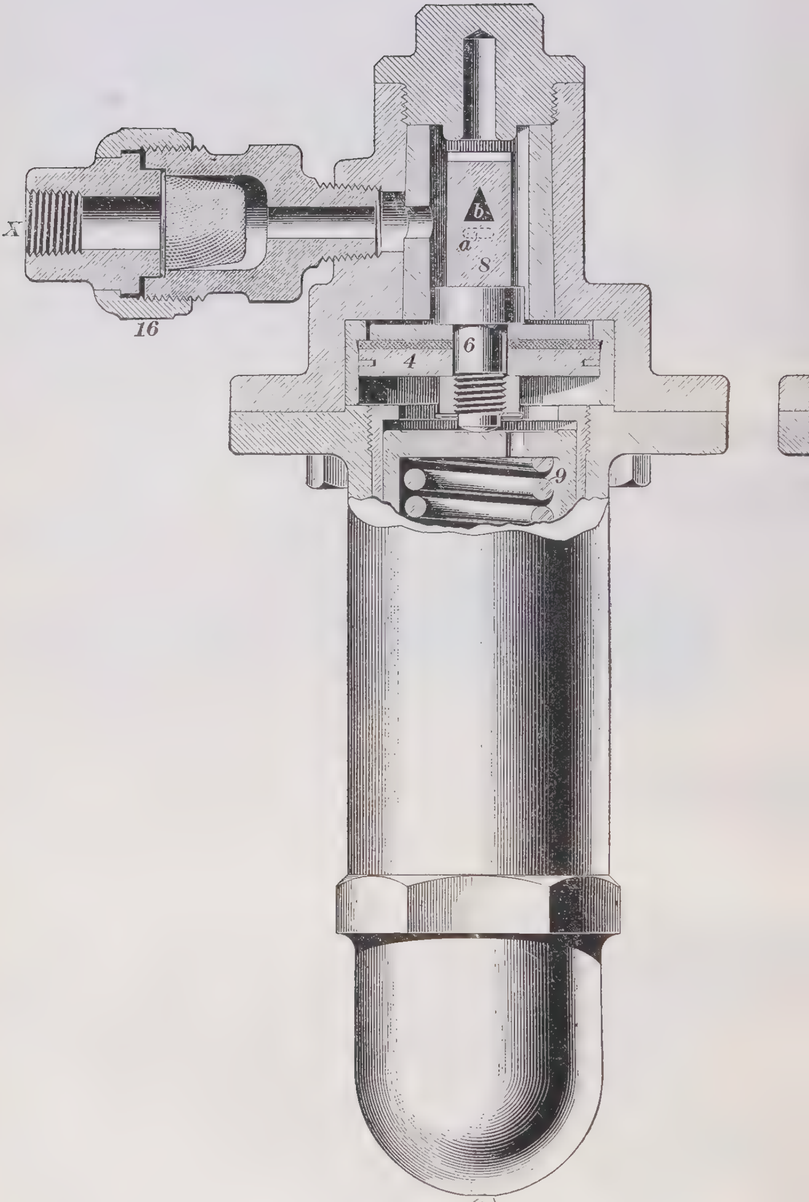
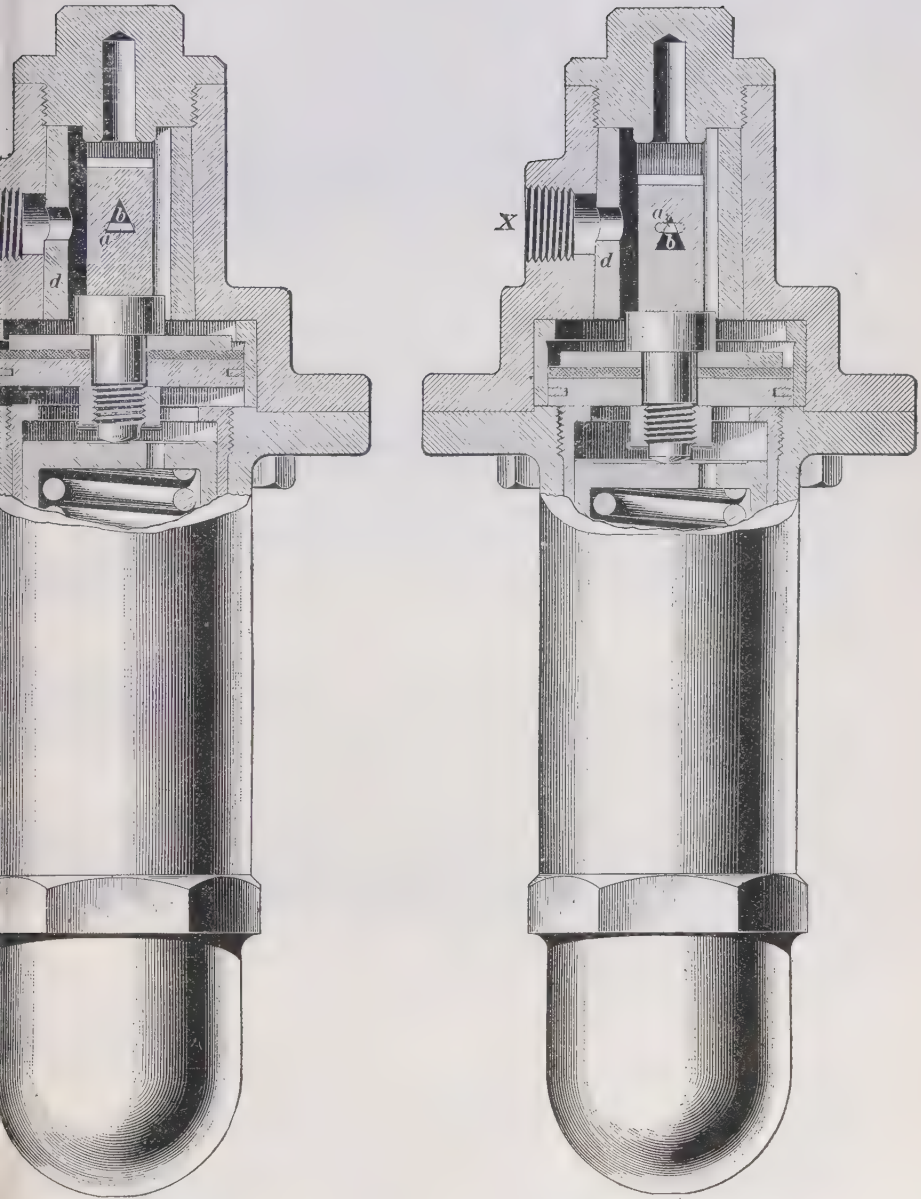


FIG. 8

11. Details of the Parts.—Views of the piston, piston stem, and slide valve of the high-speed reducing valve are given in Fig. 8, views (*a*) and (*b*). View (*a*) shows the piston and piston stem, and view (*b*) shows the valve with the spring d, and pin d_1, which connects the spring to the valve. The back of the slide valve is slotted and the part of the piston stem between the collars fits in this slot, the stem being placed between the spring and the bottom of the slot. The opening c extends entirely through the valve as shown, and the triangular port b, view (*b*) connects with the opening c. The large opening b_1 extends through the valve from one side to the other. This opening permits the air to enter the interior of the valve more freely than otherwise, and in this way holds the valve to its seat.



(a)
Release



(b)
Pressure Exceeding 60 Pounds

(c)
Emergency

Fig. 9

OPERATION OF HIGH-SPEED REDUCING VALVES

12. Service Operation.—The operation of the high-speed reducing valve will be explained by referring to Fig. 9, views (*a*), (*b*), and (*c*). These views show the upper part of the high-speed reducing valve in section, so that the face of the slide valve can be seen. When the valve is sectioned in this way, the port *a* in the valve seat, Fig. 7, is in the part of the valve which is removed. Therefore, it is necessary to show port *a* as being on the face of the slide valve. When the operation of the valve is described, port *a* is considered to be stationary, and port *b* as moving up and down past it. View (*a*) shows the position of port *a* with respect to port *b* when the pressure in the brake cylinder is less than 60 pounds, or when there is no pressure in the brake cylinder. In this position the ports do not register. When a service application is made and the brake-cylinder air which enters the reducing valve through port *X* increases in pressure above 60 pounds, the pressure above the piston *4* moves it downward and compresses the regulating spring 9. The piston moves the slide valve down with it until ports *a* and *b* assume the position shown in view (*b*), Fig. 9. In this position the extent of the opening through the slide valve to the atmosphere is indicated by white. The brake-cylinder air flows to the atmosphere through these ports until the pressure reduces to 60 pounds, when the regulating spring forces the piston and slide valve upward into their normal positions again, as shown in view (*a*). The opening through ports *a* and *b* in view (*b*) is such that the air can discharge from the brake cylinder as fast as it enters through the service ports in the slide valve of the triple valve. The pressure in the brake cylinder, therefore, cannot exceed 60 pounds.

13. Emergency Operation.—The relative positions of ports *a* and *b* in an emergency application of the brake are shown in view (*c*), Fig. 9. The air now enters the brake cylinder from the brake pipe and the auxiliary reservoir in a much greater volume than could possibly escape through the

ports *a* and *b* of the reducing valve; hence, piston *4* of the latter is forced downward the full length of its stroke, and assumes the position shown. In this position, the opening through ports *a* and *b* as shown by white, is small, and the air discharges quite slowly from the cylinder. As the pressure in the cylinder and above piston *4* gradually decreases, the regulating spring gradually raises the piston and slide valve, and, as the slide valve is raised, the opening through ports *a* and *b* gradually increases; consequently the discharge from the cylinder increases accordingly until the brake-cylinder pressure is reduced to a safe amount (60 pounds), when the reducing valve assumes its normal position, view (*a*), Fig. 9, and covers the opening *a* so that no more air can escape from the brake cylinder until the brakes are released.

It will be noted from the foregoing that the action of the reducing valve in accelerating the blow-down of the brake-cylinder pressure is due entirely to the shape of port *b*. When the slide valve is all the way down, the tip of the port is opposite the exhaust port *a* and the air can escape only slowly and, therefore, the maximum braking force is obtained. As the slide valve rises, the opening through it increases. and the air discharges more rapidly, hence the braking force decreases as the speed reduces.

OPERATING THE BRAKE

14. Making Stops.—The two-application method is used to stop trains when the PM equipment is used. A two-application stop means that the brakes are applied and released twice from the commencement of the stop until it is completed. The first reduction which is made is usually heavy, although a split reduction may be made when the train is long. A *split reduction* means that the first reduction is divided into two reductions. For example, instead of making an initial reduction of 15 pounds, two reductions of 7 or 8 pounds each are made. The split reduction prevents the run-in of the slack which would follow a heavy initial reduction when the train is long. When the speed is reduced to about 15 miles per hour, the brakes are released by placing the brake-valve handle in

full-release position, but no attempt should be made to recharge. The brake-valve handle is then placed in lap position direct, or it is kept in running position for a few seconds, depending upon the type of brake valve which is used. The stop is then completed by a light application and the brakes are released just as the train stops.

No attempt should be made to recharge when releasing the brakes after the first application, because there is no time for the brake-pipe and the auxiliary-reservoir pressures to equalize. Attempting to recharge would cause the second application to be delayed because the brake-pipe pressure would have to be reduced below the auxiliary-reservoir pressure before the brakes would apply.

A reduction of 20 pounds with either a 70-pound or a 110-pound brake-pipe pressure will give a brake-cylinder pressure of 50 pounds with an 8-inch piston travel. A service brake-pipe reduction of about 25 pounds will give a brake-cylinder pressure of about 60 pounds when the brake-pipe pressure is 110 pounds. It is a waste of air to make a heavier reduction, because the reducing valve will not allow a brake-cylinder pressure in excess of 60 pounds.

15. Changing Engines.—If an engine which carries a low pressure, such as a switch engine, is coupled to a high-pressure train, as soon as the hose is connected and the angle cocks are opened, the high brake-pipe pressure in the cars will at once pass to the brake valve in which the pressure is much less. As the pressure in chamber *D* will be considerably less than 110 pounds, the equalizing piston will be raised and held up until the entire brake-pipe pressure is reduced to that in chamber *D*. The train brakes will apply hard usually in quick action, and the automatic reducing valves will reduce the auxiliary and cylinder pressure to 60 pounds. The brake valve should not be moved to full-release position in an effort to seat the equalizing piston, but rather the valve should at once be lapped and kept lapped until the brake-pipe air has ceased flowing from the brake-pipe exhaust; this will save the excess in the main reservoir for use in releasing.

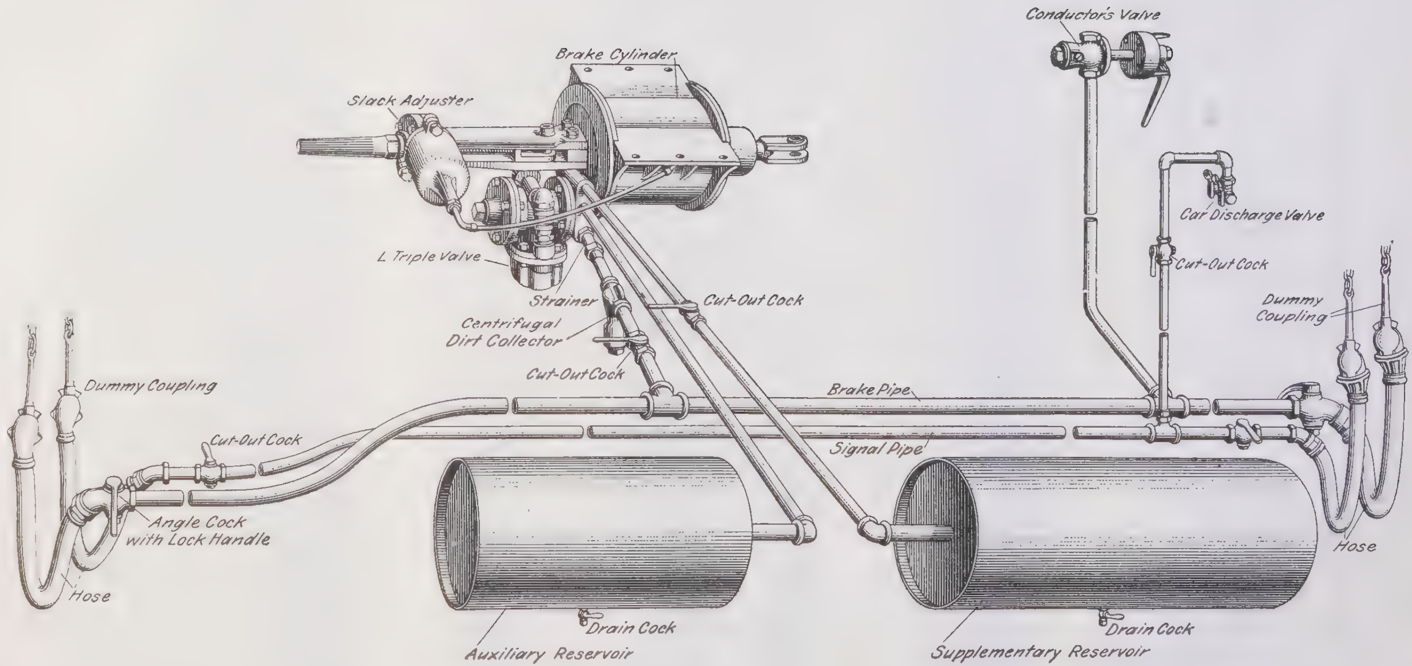

Conductor's Valve
Brake Cylinder
Slack Adjuster
Car Discharge Valve
Cut-Out Cock
L Triple Valve
Strainer
Cut-Out Cock
Dummy Coupling
Centrifugal Dirt Collector
Cut-Out Cock
Dummy Coupling
Brake Pipe
Cut-Out Cock
Signal Pipe
Angle Cock with Lock Handle
Hose
Hose
Drain Cock
Drain Cock
Auxiliary Reservoir
Supplementary Reservoir

FIG. 10

On account of the higher pressure, reductions can be made both from chamber *D* and from the brake pipe in less time than if the pressure were only 70 pounds. For that reason, the reductions from the brake valve should be made more moderately than with the 70-pound pressure, in order that any triples that are dry or sticky, or otherwise out of order, may not go into quick action.

On a long train, the triple valves on the rear cars are more liable to stick after a light application with the high pressure, as the leakage from the brake pipe to the auxiliary reservoirs past the packing rings will be no less and the pressure on the slide valve is much more than 70 pounds. They are not likely to stick after a moderately heavy reduction, as in that case there is a greater difference between the brake-pipe pressure and that of the main reservoir.

A very heavy service reduction (over 20 pounds), should not be used at a slow speed, as the consequent high-cylinder pressure may cause the wheels to slide. Emergency applications should not be made if the speed of the train is less than 40 miles per hour, unless in an emergency; the wheels are apt to slide at slow speeds.

THE LN PASSENGER BRAKE EQUIPMENT

DESCRIPTION OF BRAKE

16. Arrangement of Equipment.—The brake equipment which was next introduced for passenger cars only was known as the LN passenger brake equipment. This equipment derives its name from the fact that a type L triple valve is used in combination with a type N brake cylinder.

The arrangement of the LN equipment is shown in Fig. 10. The principal parts are the triple valve, the brake cylinder, the auxiliary reservoir and the supplementary reservoir. The triple valve, as with the PM equipment, is bolted to the pressure head of the brake cylinder, and the brake-pipe branch pipe as well as the pipes from the auxiliary reservoir and the supplementary reservoir are connected to this head. This construction

permits of the triple valve being removed and replaced without the necessity of breaking any pipe joints. A safety valve set for 62 pounds is screwed into the triple valve and limits the brake-cylinder pressure to this amount in a service application.

NEW FEATURES OF LN EQUIPMENT

17. The LN equipment has all the features of the PM equipment, and, in addition, has several new features. The names and the description of these new features follow:

18. Quick Recharge of Auxiliary Reservoirs.—The quick-recharge feature permits the brakes to be recharged at about the same rate as they release, and thereby insures the ability to make such successive applications as are required through yards, down grades, etc., without any material loss in maximum braking force. The quick-recharge feature is accomplished by providing a charging port in the triple valve in addition to the feed groove, and also by designing the triple valve so that, when it is in release position, it connects the supplementary reservoir with the auxiliary reservoir. As the air in the supplementary reservoir is not used when the brakes are applied in service, the auxiliary reservoir under ordinary braking conditions charges up rapidly from the supplementary reservoir and from the brake pipe.

19. The Quick-Service Feature.—The quick-service feature causes the brakes to apply more rapidly than otherwise when a service-brake application is made.

The more rapid application of the brakes is brought about as follows: When the brake-pipe pressure is reduced at the brake valve, the triple valve next to the engine, in addition to its normal operation, vents a small amount of brake-pipe air to the brake cylinder, and thereby causes a sudden slight reduction in brake-pipe pressure. This sudden reduction of pressure causes the next triple valve to operate in the same way, and this triple operates the next one, and so on, the result being that all triple valves in the train move quickly to service position. Therefore, the ports through which the air from the auxiliary reservoirs passes to the brake cylinders opens

quickly and the brakes apply rapidly. The same principle is employed to produce quick service during a service application, as is used to produce to quick action in an emergency application, with the exception that less air is vented to the brake cylinder in quick service, and, consequently, this action is less severe.

The quick-service feature then reduces the interval between the application of the first and the last brake, and lessens the shocks which are caused by the slack running in on account of the head-end brakes applying so much sooner than the rear ones.

20. The Graduated-Release Feature.—The graduated-release feature permits the brakes to be partly or entirely released when making a stop. The graduated release, which means that the pressure in the brake cylinders is reduced gradually or by steps, is accomplished by the proper operation of the brake valve in conjunction with the operation of the triple valve in connecting the supplementary reservoir with the auxiliary reservoir.

21. A High Brake-Cylinder Pressure in Emergency.—A high pressure is developed in the brake cylinder in an emergency application, and is retained during the complete stop. This feature is accomplished by the triple valve, which, in addition to venting the air from the brake pipe to the brake cylinder in the usual way, also connects the brake cylinder to the auxiliary reservoir and the supplementary reservoir. The combined volume of these reservoirs is so large that the pressure contained in them reduces very little when they are connected to the brake cylinder. The pressure at which the reservoirs and the brake cylinder equalize, is about 104 pounds when the brake-pipe pressure is 110 pounds. The pressure is retained during the stop because the triple valve cuts out the safety valve during an emergency application.

It will be noted that the brake-cylinder pressure, which is obtained in emergency with the LN equipment, is not reduced, as the speed decreases as it does with the PM equipment. The reason for this is that the brake shoes act as a substitute for the high-speed reducing valve. The temperature of the brake

shoes is so high when an emergency stop is made with the heavy cars on which the LN equipment is used, that the brake-shoe friction is not enough to cause the wheels to slide. With the comparatively light wooden cars on which the PM equipment is used, it is necessary to use a high-speed reducing valve, because the brake shoes do not become so hot and the brake-shoe friction is, therefore, higher.

22. Quick Action and Emergency-Cylinder Pressure After a Service Application.—The triple valves will operate quick action and will cause an emergency pressure to be developed in the brake cylinder after a considerable service application has been made. The maximum braking force can, therefore, be obtained when it is most likely to be needed, that is, after a service application, and an emergency arises which requires a quick stop. Tests have shown that after a service reduction of 30 pounds, an emergency application would give a brake-cylinder pressure of 100 pounds, and would also cause quick action to be transmitted throughout the train.

OPERATING THE BRAKE

23. Graduated Release.—As will be explained farther on, a graduated release with the LN equipment causes the train brakes to be released in steps or graduations as opposed to the complete release that occurs with the PM equipment.

24. To graduate the release, the pressure in the brake pipe is increased enough to move the triple valves to release position, and the automatic brake valve is then lapped, this operation being continued until the brakes are completely released. With trains of over five cars, release position is used for the first graduated release, and running position for the other graduations; but with trains of five cars or less, running position is used for all graduations. The reason is that the slide valves have to be moved to release position for the first graduation, and this requires a higher pressure on a long train than on a short one; but as the subsequent graduations require only a movement of the graduating valves, running position can be used with any length of train.

25. Stopping With Graduated Release.—In the absence of specific instructions, a graduated-release stop should be made as follows: A reduction of 12 or 15 pounds, depending on the speed and the grade, is made while working steam. A split reduction should be made, that is, the initial reduction should be divided into two with a slight interval between, so as to avoid harsh slack action. The first reduction should not exceed 7 pounds. Next, the throttle should be gradually shut off or reduced to a drifting throttle. The speed should be down to 12 or 15 miles per hour at about 400 feet from the stopping point. Then two or three graduated releases should be made, as explained in Art. **24,** and the stop completed with a light pressure in the brake cylinders if the train is on level track and consists of more than nine cars. With a shorter train, the brakes should be fully released just as the train stops.

26. The first graduated release is obtained by leaving the brake valve in full release for a second or two if the length of train warrants, and then moving to lap. This should increase the pressure about 4 pounds. The time in running position for the other graduations depends on conditions, but the increase in brake-pipe pressure should not be less than 2 pounds.

27. Stopping Without Graduated Release.—A stop without a graduated release requires a two-application stop, as with the PM equipment. The preliminary movement of the brake valve and the throttle is the same as explained in Art. **25,** and the speed is reduced the same amount before the release is started. The brake valve is next moved to release position for the required time, and then to running position. This completes the first application. Then a reduction of 5 pounds is made and followed with a little more when necessary, and the brakes are released just as the train stops if the train is of less than nine cars, otherwise the brakes are to be held applied.

The release of the brakes is usually followed by a kick-off, this meaning that the handle of the automatic brake valve is placed in release position for one second and then moved to running position. This releases any brakes on the head end that may have applied on account of the recharge at the rear.

DESCRIPTION OF THE PARTS

28. The Supplementary Reservoir.—The purpose of the supplementary reservoir is to store the air which is used to obtain the graduated release of the brake, and the high brake-cylinder pressure in emergency. The air in this reservoir also assists the brake-pipe air to recharge the auxiliary reservoir. The supplementary reservoir may be cut out of service by closing the cut-out cock in the pipe which connects the reservoir to the brake cylinder. The supplementary reservoir is about two and one-half times as large as the auxiliary reservoir.

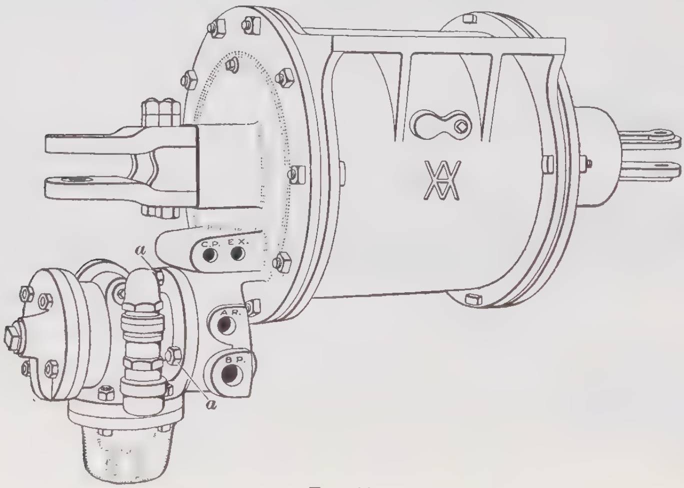


Fig. 11

29. Triple Valve and Brake Cylinder.—An exterior view of the type L triple valve and the type N brake cylinder is shown in Fig. 11. The triple valve is attached to the cylinder head by studs and nuts *a*, two of which are shown. The triple valve is of the pipeless type because all the pipes are connected to the brake-cylinder head. Letters which are cast on the brake-cylinder head indicate where the various pipes are to be connected. The brake pipe is connected at *B. P.*, the auxiliary reservoir at *A. R.*, and the supplementary reservoir at *C. P.* The triple-valve exhaust port is marked *EX.* If

found more convenient, the pipes may be connected to corresponding holes on the opposite side, in which case the holes which are not used are closed by plugs.

30. Cylinder Head.—A front view of the cylinder head with the triple valve removed from it, is shown in Fig. 12. The port marked *To Supp. Res.* leads through the cylinder head to

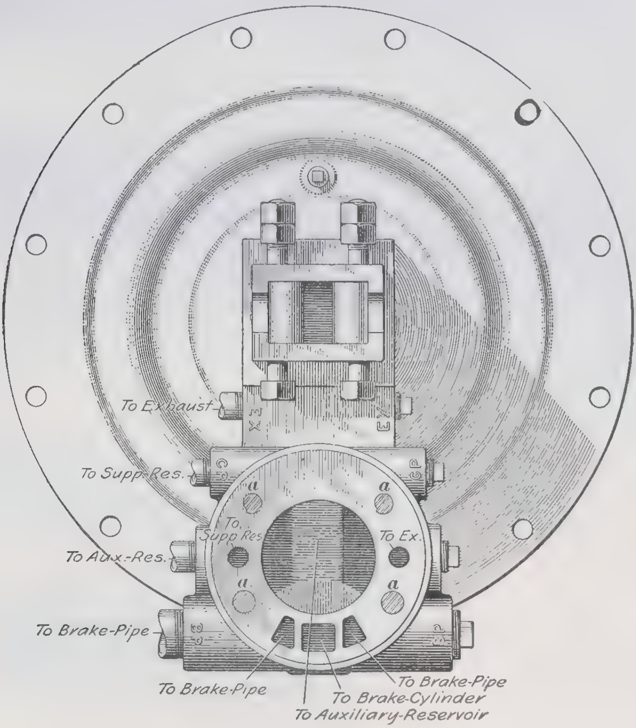


Fig. 12

both of the supplementary-reservoir connections *C. P.*, the port marked *To Ex.* leads to both of the exhaust-port connections; the ports marked *To Brake Pipe,* lead to the brake-pipe connections *B. P.;* the port *To Brake Cylinder* leads through the brake-cylinder head to the brake cylinder, and the large opening in the center is connected by passages to the auxiliary-reservoir connections shown. All of the ports which are shown

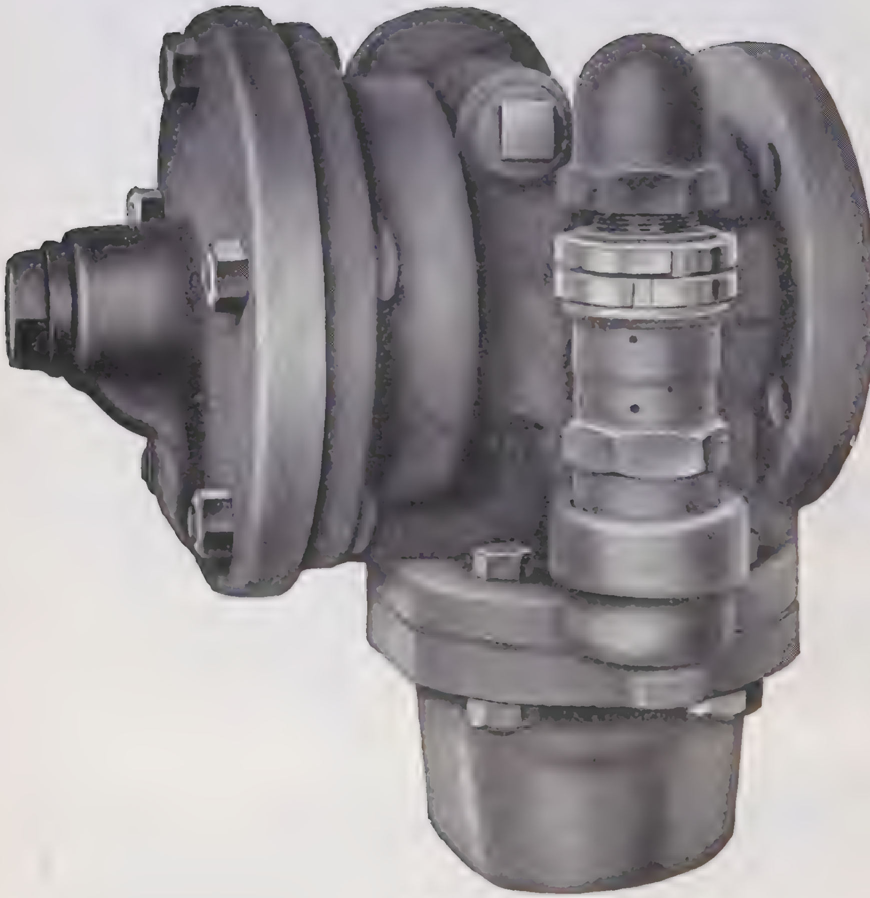


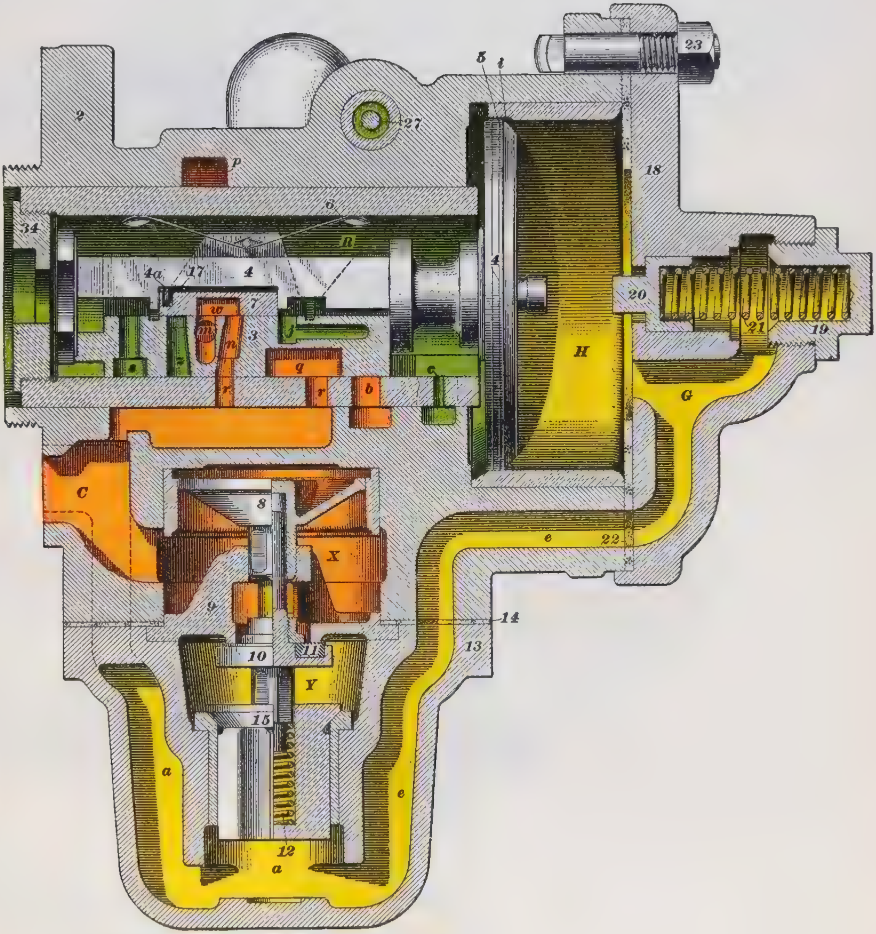
FIG. 13

Fig. 14

in the face of the cylinder head, as well as the large opening in the center, register with corresponding ports in the triple valve when it is bolted to the head. A gasket on the triple-valve face of the cylinder head prevents air from leaking between the ports where the triple valve is bolted to the head.

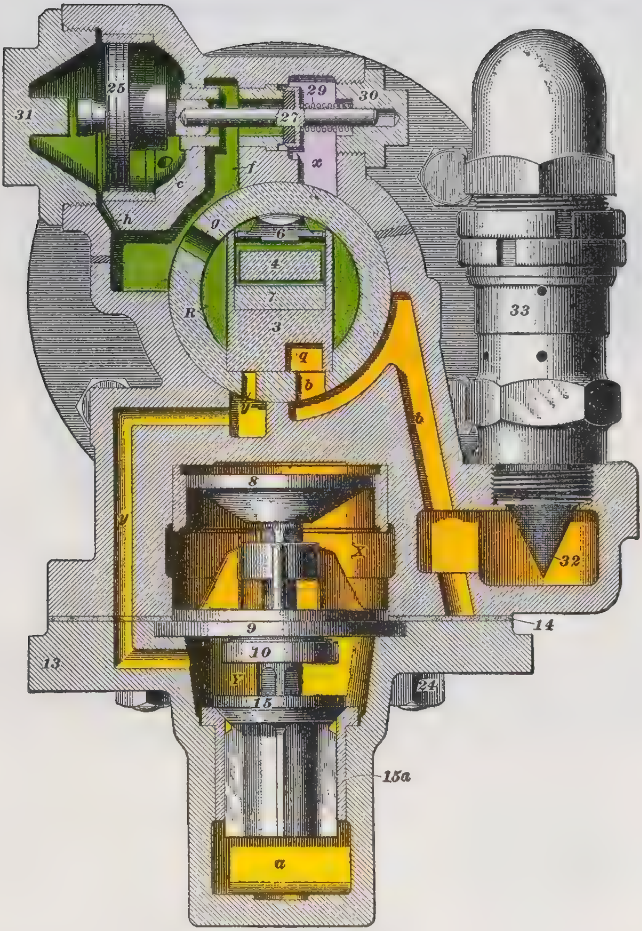
31. Views of L Triple Valve.—Figs. 13 and 14 show the L triple valve as viewed from opposite sides. Fig. 15 is a sectional view taken lengthwise through the triple valve and Fig. 16 is a cross-sectional view. The L triple valve used with 8- and 10-inch brake cylinders is known as the *L-1-B;* the one used with 12- and 14-inch brake cylinders is known as the *L-2-A;* and the *L-3* is used with 16- and 18-inch cylinders. These letters and numerals are cast on the side of the valve body.

32. Names of Parts.—Referring to Figs. 15 and 16, the names and numbers of the parts of the L triple valve are: *2,* triple-valve body; *3,* slide valve; *4,* main piston; *5,* piston ring; *6,* slide-valve spring; *7,* graduating valve; *8,* emergency piston; *9,* emergency-valve seat; *10,* emergency valve; *11,* rubber seat for emergency valve; *12,* check-valve spring; *13,* check-valve case; *14,* check-valve case gasket; *15,* check-valve; *15a,* check-valve bushing; *17,* graduating-valve spring; *18,* cylinder cap; *19,* graduating-spring nut; *20,* graduating stem; *21,* graduating spring; *22,* cylinder-cap gasket; *23,* cylinder-cap bolt and nut; *24,* check-valve-case bolt and nut; *25,* by-pass piston; *27,* by-pass valve (the by-pass piston is provided with a packing ring to prevent air from leaking past the piston, and the by-pass valve is provided with a rubber seat to prevent air from leaking past the valve when it is in its closed position); *29,* by-pass-valve spring; *30,* by-pass-valve cap; *31,* by-pass piston cap; *32,* safety-valve strainer; *33,* safety valve; and *34,* end cap.



58B-I L T 26C-291 § 11

Fig. 15



58B-I L T 26C-291 § 11

Fig. 16

DETAILS OF THE PARTS

33. Main Piston, Graduating Valve, and Spring. In Fig. 17 views (*a*), (*b*) and (*c*), is shown the main piston *4*, the graduating spring and the graduating valve *7*. The pin *4a* extends through a hole in the spring and holds the

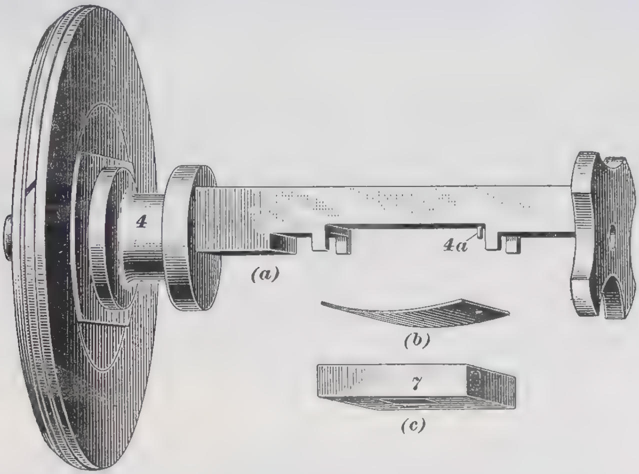


FIG. 17

graduating spring in position. This pin also fits into a hole (shown by dotted lines) in the graduating valve when the parts are assembled, and thereby prevents the valve from being applied to the piston wrong end to. The purpose of the spring is to keep the graduating valve on its seat when there is little or no air pressure on the slide valve, so that dirt cannot get between the valve and its seat.

Fig. 18 is a view of the face of the graduating valve and shows the cavities *w* and *v*.

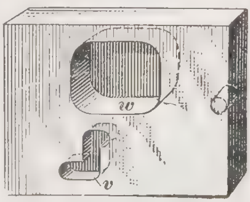
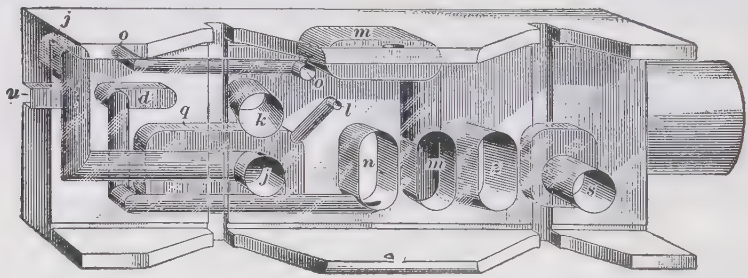


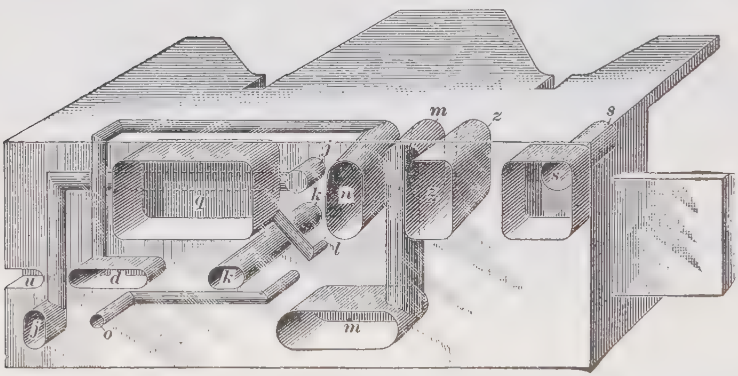
FIG. 18

34. The Slide Valve.—Fig. 19 (*a*) and (*b*) shows two transparent views of the slide valve. In (*a*) is shown a view of the top of the slide valve, which forms the seat for the graduating valve, and

in (*b*) is shown a view of the face of the slide valve. These views represent the slide valve as transparent in order to show clearly the form, location, and relative positions of the ports, passages and cavities. The projection shown in



(*a*)



(*b*)

Fig. 19

views (*a*) and (*b*) at the right-hand end of the slide valve, is called the slide-valve stop. The purpose of the various ports, passages, and cavities in the slide valve will be understood when the operation of the triple valve is explained.

35. The Slide-Valve Seat.—In Fig. 20 is shown a sectional view of the slide-valve bushing with the upper part

removed, so as to make clear the slide-valve seat and the ports in it. The purpose of the ports and the places to which they

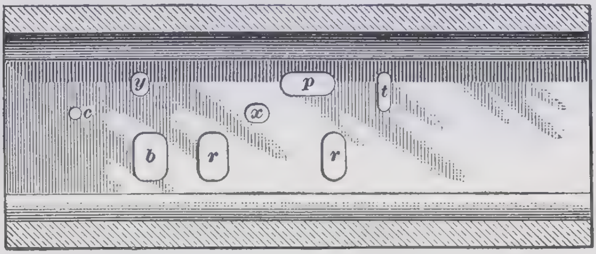


FIG. 20

lead, will be explained when the operation of the triple valve is considered.

36. By-Pass Piston, By-Pass Valve, and Spring. In Fig. 21 is shown the by-pass piston *25,* the by-pass valve *27,* and the by-pass valve spring *29.* The purpose of the piston *25* is to unseat the by-pass valve when the brakes are

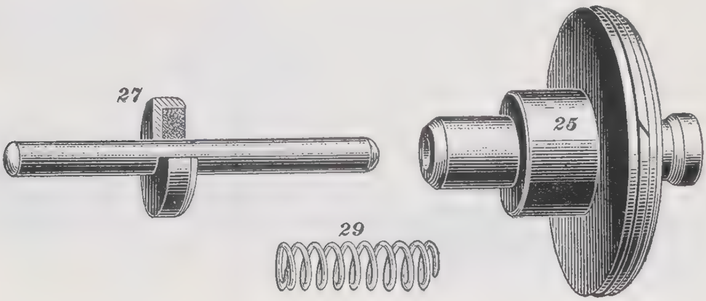


FIG. 21

applied in emergency, at which time the valve *27* connects the auxiliary reservoir and the supplementary reservoir. The valve *27* has a rubber seat to prevent the air from the supplementary reservoir from leaking to the auxiliary reservoir during service applications. The spring *29* seats the by-pass valve and holds it to its seat after an emergency application.

37. The End Cap.—The end cap *34* is shown in Fig. 22. This cap is screwed into the auxiliary-reservoir end of the slide-valve bushing, Fig. 15, and acts as a stop for the main piston and the slide valve when they are moved to release position. In this position, the slide-valve stop, Fig. 19 (*a*) and (*b*), strikes the end cap.

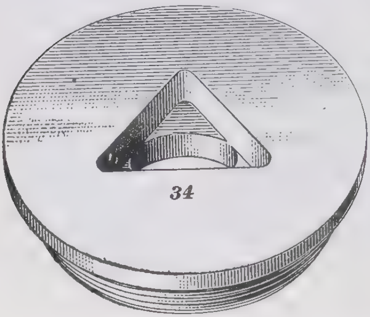


Fig. 22

38. Emergency Parts of Triple Valve.—The emergency parts of the L triple valve are shown in Fig. 23. They consist of the following parts: the emergency piston *8* shown in section; the emergency valve *10* with rubber seat; the check

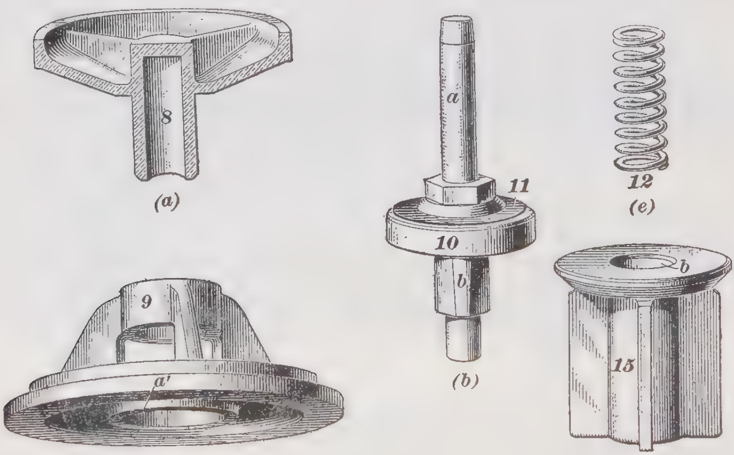


Fig. 23

valve *15;* the emergency valve seat *9;* and the check valve spring *12*. These parts require no description, as they are the same as the emergency parts of a freight-triple valve which has already been explained.

OPERATION

39. As the construction of the L triple valve makes it impossible to section it so as to show all the movable parts, ports, and passages on one plane, a series of conventional views is shown in Figs. 24 to 29, inclusive. It should be borne in mind that these conventional views are given to assist in explaining the operation of the type L triple valve and simplify the tracing of the flow of air through it, but do not represent its actual appearance.

40. Charging.—When the triple valve is in charging position, the auxiliary reservoir and the supplementary reservoir are charged to standard brake-pipe pressure with air from the brake pipe. The air from the brake pipe passes through the passages *a*, *e*, and *G* into chamber H, and moves the main piston *4*, the slide valve and the graduating valve to the right to full-release position, Fig. 24, provided they are not already in that position. This movement opens the feed-groove *i* and allows the brake-pipe air to pass into chamber *R* and thence to the auxiliary reservoir. The pressure in passage *a* raises the check valve *15* and the air passes into chamber *Y*, and as port *y* in the slide-valve seat and port *j* in the slide-valve register, brake-pipe air can also pass through ports *y* and *j* into chamber *R* and the auxiliary reservoir. Port *k* in the slide valve registers with port *x* in the slide-valve seat, so that air can pass from chamber *R* through ports *k* and *x* to the supplementary reservoir, which is charged at the same time and to the same pressure as the auxiliary reservoir. In this position of the slide valve, port *c* in the seat is not covered; hence, the chamber back of the by-pass piston into which port *c* opens is charged to auxiliary-reservoir pressure. The chamber in front of the by-pass piston into which port *h* opens is at all times connected to chamber *R* and the auxiliary reservoir through the ports *g* and *h*; thus, the pressure on both sides of the by-pass piston *25* are always equal in this position. Also, port *f* leads from port *g* to the chamber in front of the by-pass valve *27*, and this chamber is likewise charged to auxiliary-reservoir pres-

sure. In charging position, port *n* in the slide-valve registers with port *r* in the seat, cavity *w* in the graduating valve connects the upper ends of the ports *n* and *m*, and port *m* in the slide-valve face registers with the exhaust port *p*, so that any air in the brake cylinder can pass to the atmosphere.

41. Quick Service.—The triple valves, when they operate in quick service, permit the air from the auxiliary reservoirs to enter the brake cylinders. Each triple valve also vents a small amount of air from the brake pipe to the brake cylinder and thereby causes a rapid serial application of the brakes throughout the train. The triple valve is shown in quick-service position in Fig. 25. The operation of the triple valve in quick service is as follows:

When a service reduction is made, the pressure in the brake pipe and chamber *H* is reduced faster than the air from the auxiliary reservoir can pass back through the feed-groove *i*. As the auxiliary-reservoir pressure in chamber *R* is then greater than that in chamber *H*, the main piston *4* will be moved to the left and will close the feed-groove *i*, and thereby shut off the communication between the brake pipe and the auxiliary reservoir. The graduating valve *7* moves with the main piston *4* and closes ports *j*, *m* and *k* at the top of the slide valve and thus closes the communication between the auxiliary and the supplementary reservoirs, between Chamber *Y*, and the slide-valve chamber *R*, and between the brake cylinder and the atmosphere. It also uncovers port *z*, and cavity *v* in the graduating valve connects ports *l* and *o*. As the main piston *4* continues to move, the shoulder on the end of its stem engages the slide valve; all these parts then move together until the knob on the main piston *4* strikes the graduating sleeve; the triple valve is then in quick-service position. In this position, port *z* registers with port *r* and the auxiliary-reservoir air passes through *z* and *r* and passage *C* to the brake cylinder; ports *y* and *o* register so that brake-pipe air from chamber *Y* passes through these ports and through cavity *v* in the graduating valve, port *l*, cavity *q*, port *r*, and the passage *C* to the brake cylinder. The pressure in chamber *Y* being reduced,

check-valve *15* will rise and allow brake-pipe air from passage *a* to be supplied to this chamber as fast as it passes out through port *y*. The cavity *q* in the slide valve connects port *r* with port *b* and thereby establishes communication between the brake cylinder and the safety valve. The safety valve is set to withstand a pressure of 62 pounds, and it, therefore, limits the brake-cylinder pressure to this amount.

42. The venting of the brake-pipe air to the brake cylinder in quick service constitutes the quick service feature of the triple valve. The reason why this feature causes the brakes to apply more rapidly than usual is as follows: The sudden local reduction in the brake-pipe pressure which is made when the first triple valve moves to quick-service position causes the triple valve, which is next to it, to move quickly to quick-service position and vent brake-pipe air to the brake cylinder, and this action is transmitted rapidly from triple valve to triple valve throughout the train. The prompt movement of the triple valves, which accompanies the venting of the brake-pipe air, causes the service ports in these valves to open quickly, and the brakes, therefore, apply more rapidly than if the total brake-pipe reduction were made at the brake valve. In the latter event, the brakes would apply slowly on long trains because the air from the auxiliary reservoirs cannot pass to the brake cylinders any faster than the air escapes from the brake pipe. The local reduction in brake-pipe pressure which occurs in quick service, will not cause an emergency application, because the air must pass through the restricted port *l*. The tendency to produce quick action is also guarded against by proportioning the valves and locating the ports so that the service port *z* will not fully register with port *r* while port *y* is connected to port *o*, and any movement which tends to compress the graduating spring will increase the opening of the service port *z* and decrease the opening through port *y*. This gradually increases the rate of discharge from the auxiliary reservoir, and decreases the rate of discharge from the brake pipe, until port *z* is opened its full extent and port *y* is entirely closed.

43. Full Service.—In full-service position, the air which enters the brake cylinder comes from the auxiliary reservoir only. The triple valves move to full-service position when the train is comparatively short. The operation of the triple valve in full-service position, Fig. 26, is as follows: When a service reduction is made with a short train, the brake-pipe pressure will reduce faster than when the train is long, and the result will be that a greater difference will be formed between the brake-pipe pressure and the auxiliary-reservoir pressure. This will cause the triple piston to compress the graduating spring slightly and move the slide valve and graduating valve a little beyond quick-service position until port *o* ceases to register with port *y*. The triple is then in full-service position. When the slide valve is in this position, ports *z* and *r* register fully, the quick-service port *y* is blanked by the slide valve, and no brake-pipe air can pass to the brake cylinder from chamber *Y*. The local reduction of brake-pipe pressure at each triple valve is thus prevented, for the reason that it is not necessary, because the reduction is now as quick as desirable. The brakes apply promptly, because the service port *z* is fully opened. The brake cylinder is connected through port *r* and cavity *q* and port *b* to the safety valve as in quick-service position.

44. Lap.—The brake-valve handle is placed in lap position after a sufficient reduction has been made to produce the desired application of the brakes, and this position of the brake valve prevents the farther escape of air from the brake pipe. The flow of air from the auxiliary reservoir to the brake cylinder continues as in Figs. 25 and 26 until the pressure on the reservoir side of the piston *4* reduces slightly below the pressure which remains on the brake-pipe side. The greater pressure in the brake pipe, with the assistance of the graduating spring, moves the piston and the graduating valve from their position, Fig. 25, to quick-service lap position, Fig. 27. In this position the graduating valve blanks the upper end of port *z*, and thereby stops the passage of air from the auxiliary reservoir to the brake cylinder. The triple piston stops when its shoulder strikes the slide valve, because the slight difference of pres-

sure which is sufficient to move the piston and the graduating valve is unable to overcome the resistance of the slide valve, which, therefore, remains in service position.

When the triple valve is in lap position it will require only a slight reduction in brake-pipe pressure to apply the brake, because the triple piston and the graduating valve are the only parts which need to be moved. Further reductions may be made until the pressure in the brake cylinder builds up to 62 pounds, after which the safety valve will prevent any higher brake-cylinder pressure. With a brake-pipe pressure of 110 pounds, a brake-pipe reduction of 25 pounds will apply the brakes to the adjustment of the safety valves.

The exact position of the main-slide valve in lap position will depend on whether it is in quick-service or full-service position. In full-service lap position, the main-slide valve would be in the position shown in Fig. 26 and the graduating valve in the position shown in Fig. 27.

45. Release and Recharge.—After the brakes have been applied, if the brake valve is placed and left in running position, the auxiliary reservoirs will be recharged from the brake pipe and from the supplementary reservoir. This constitutes the quick-recharge feature of the triple valve. The operation of the triple valve, when it is in release and recharging position, will be explained by referring to Fig. 24, which shows the triple valve in charging position, because the position of the triple valve is the same in both these positions. When releasing the brakes, the brake-pipe pressure and the pressure in chamber *H* is increased above the auxiliary-reservoir pressure; that is, the pressure in chamber *R*. This causes the main piston *4*, with the slide valve and the graduating valve, to be moved to release and charging position, Fig. 24.

In this position, the air on the brake cylinder is exhausted through ports *r* and *n*, cavity *w* in the graduating valve, port *m* in the slide valve to the exhaust passage *p* and the atmosphere, while the auxiliary reservoir is recharged from the brake pipe through the ports *y* and *j* and the feed-groove *i*, as described in Art. **40**.

The supplementary reservoir is connected to the auxiliary reservoir through port *x* and passage *k*, and the supplementary-reservoir air which remained at its initial pressure during service applications, now flows into the auxiliary reservoir and helps to recharge it. During the recharge the pressures on the brake-pipe and on the auxiliary-reservoir sides of the main piston *4* are in balance. This balance of pressure insures a quick response of the brakes if at this time it becomes necessary to make a reduction.

If the brake-valve handle is moved to and left in running position, the brake-pipe pressure will be fully restored and the piston *4* will remain in release position. The brakes will, therefore, fully release and the auxiliary reservoir and the supplementary reservoir will fully recharge. The action which will occur if the brake valve is not left in running position will be explained in the next Section.

46. Graduated Release.—Graduated release means that the pressure in the brake cylinder is reduced in a series of steps or graduations when a stop is being made, instead of the air being discharged at one time as with other types of triple valves when they go to release position. The operation of the triple valve in releasing the brake a little at a time is as follows: Suppose that only sufficient air is permitted to flow into the brake pipe to move the piston and its attached valves to release position, Fig. 24, and that the brake valve is then returned to lap position. The flow of air from the supplementary reservoir to the auxiliary reservoir through port *x* and passage *k* will continue after the increase in brake-pipe pressure has ceased, and the pressure on the auxiliary-reservoir side of the piston *4* will increase slightly above the pressure on the brake-pipe side and will thereby cause the piston and the graduating valve *7* to move to the left to graduated-release lap position, Fig. 28. The movement to the left will be arrested when the collar on the rear of the piston stem strikes the slide valve, because the difference in the pressures is not sufficient to overcome the resistance of the slide valve. In this position, the graduating valve closes the exhaust port *m* and

thus prevents the further flow of air from the brake cylinder to the atmosphere. This valve also closes port *k* and prevents the further recharging of the auxiliary reservoir from the supplementary reservoir, and closes port *j* and thus prevents the recharge of the auxiliary reservoir from the brake pipe. The triple piston closes feed-groove *i*, so that the auxiliary reservoir cannot charge from this source.

The brake is, therefore, only partly released, and some of the air which was originally in the brake cylinder still remains there. If the brake-valve handle is again placed in running position, which increases the brake-pipe pressure, and is then returned to lap, the same action will occur as has already been explained. This operation may be repeated as desired until the pressure in the supplementary reservoir has equalized with the pressure in the auxiliary reservoir and when this takes place, the brakes will completely release. The amount of the reduction in the brake-cylinder pressure for any given graduation depends upon the amount the brake-pipe pressure has been restored. For example, if the pressure in the brake pipe has been increased 5 pounds, the triple valve will reduce the pressure in the brake cylinder the same amount before the discharge of the air from the brake cylinder stops.

The L triple valve then permits of the brakes being released in two ways, at once or in graduations, depending on how the brake valve is operated. If the brake-valve handle is left in running, a complete release of the brakes will occur, but if the handle is allowed to remain in running position for a short interval and is then moved to lap position, the release of the brakes will be graduated.

47. Emergency.—The triple valve, when it is in emergency position, allows the air in the auxiliary and the supplementary reservoirs to discharge to the brake cylinder, and as the safety valve is cut out of service, the brake-cylinder pressure is retained until the stop is completed and the brakes are released. Emergency action is transmitted throughout the train as with other triple valves, that is each triple valve causes a heavy sudden reduction in brake-pipe pressure by venting

brake-pipe air to the brake cylinders. The detailed operation of the triple valve in emergency is as follows: When the brake-pipe pressure is reduced suddenly or when the brake-pipe pressure reduces more rapidly than the auxiliary-reservoir pressure, the piston is forced to the extreme left and compresses the graduating spring.

The end of the slide valve uncovers port *t* in the slide-valve seat, and thus allows auxiliary-reservoir air to pass into the chamber above the emergency piston, thereby forcing this piston down and unseating the emergency valve *10*. The air in chamber *Y* escapes to the brake cylinder; and the brake-pipe air in passage *a* raises the check-valve *15* and flows into the brake cylinder in large volume through chambers *Y* and *X* and passage *C*. This produces a local reduction in brake-pipe pressure that causes the next triple valve to operate quick action, and so on throughout the train. At the same time port *d* in the slide valve registers with port *c* in the seat and allows the air in the chamber back of the by-pass piston *25* to escape to the brake cylinder through ports *c, d, n, r,* and *C*. The pressure in the chamber back of the by-pass piston *25* will be considerably reduced and the by-pass piston will be moved backward by the auxiliary-reservoir pressure in the chamber in front of it. This movement of the by-pass piston will unseat the by-pass valve *27* and thus connect the supplementary reservoir with the auxiliary reservoir through ports *x, f,* and *g*. This gives, in effect, an auxiliary-reservoir volume approximately three and one-half times the size of the one that supplies the air to the brake cylinder during a service application of the brake. The combined volumes of the auxiliary reservoir and the supplementary reservoir then pass through port *s* in the slide valve and port *r* in the seat to the brake cylinder.

Check valve *15* will remain unseated until the brake-cylinder pressure is nearly equal to the brake-pipe pressure; the emergency valve *10* will be seated as soon as the auxiliary and brake-cylinder pressures equalize; and the by-pass valve will remain unseated until the auxiliary-reservoir and brake-cylinder pressures are nearly equal to the pressure which remains in the supplementary reservoir. This action will result in a

brake-cylinder pressure of 104 pounds with a brake-pipe pressure of 110 pounds, and as cavity *q* in the slide valve is moved from over port *r* the safety valve is no longer connected to the brake cylinder; consequently this high brake-cylinder pressure will be maintained until the brake is released in the usual manner.

48. Emergency After a Service Application.—The brakes can be applied in emergency after a considerable service reduction because the brake-cylinder pressure is much less than the brake-pipe and the auxiliary-reservoir pressure. A brake-pipe reduction of 25 pounds will give a brake-cylinder pressure of about 60 pounds with standard piston travel. If the brake-pipe pressure was 110 pounds, a pressure of 85 pounds would remain in the brake pipe and in the auxiliary reservoir. An emergency application with the triple valves in good condition would cause sufficient pressure to be admitted above the emergency piston to unseat the emergency valve. In addition the pressure behind the by-pass piston would be reduced sufficiently for this piston to unseat the by-pass valve, and thereby connect the supplementary reservoir to the auxiliary reservoir.

OVERCHARGED BRAKE PIPE

49. Reducing the Overcharge.—If the brake pipe is overcharged, with the freight brake and the PM equipments, the pressure can be reduced to standard by applying and releasing the brakes one or more times. A somewhat different procedure must be followed with the LN equipment when the brake pipe is overcharged. With the LN equipment, an overcharge of 5 pounds can be reduced by decreasing the pressure in the brake pipe to 60 pounds and then releasing. If the overcharge is heavy, the procedure should be as follows: Reduce the brake-pipe pressure to 60 pounds, and after the brake-valve exhaust stops recharge the brake pipe, from full release position of the valve, to 5 pounds below the pressure that was in the brake pipe when it was overcharged. Reduce the pressure to 60 pounds, again recharge to 5 pounds less

than the previous recharge, and continue the operation until the recharged pressure is equal to the standard brake-pipe pressure. When recharging, observe the No. 2 or small duplex air gauge and avoid raising the pressure above that to which it is to be recharged. Before proceeding, inspect all brakes to see that they are released. If there is not time to reduce the overcharge, maintain the high pressure and reduce it at the next stop.

Retaining valves are to be used with the LN equipment whenever the conditions are such as to prevent the brake-pipe pressure from being recharged to 80 pounds. When the retaining valves are cut in, the brakes must not be graduated off, but must be released as with the PM equipment; that is, the brake valve must be left in full release position until the pressure is near standard, and then moved to running position.

TYPE E-7 SAFETY VALVE

50. The E-7 safety valve is a special valve and is not used for general purposes. It is attached to and made a part of the type L triple valve. This safety valve is screwed into the opening that connects to port *b* in the seat of the triple slide valve and is subjected to brake-cylinder pressure at all times except when the triple slide valve is in emergency position. The regulating spring is ordinarily set to withstand a pressure of 62 pounds acting on the under side of valve *4*; consequently, in service applications of the brake, the safety valve serves the same purpose as the high-speed reducing valve, in that it prevents the brake-cylinder pressure from increasing above the amount for which it is adjusted. In emergency applications, however, the safety valve has no control whatever over the brake-cylinder pressure, because, with the triple in emergency position, the slide valve closes the communication between the brake cylinder and the safety valve.

51. Description.—Figs. 30 and 31 show two sectional views of the E-7 safety valve. In Fig. 30, the valve is shown in its normal, or closed, position; and in Fig. 31 the valve is shown in its open position. Referring to Figs. 30

and 31, the names and numbers of the parts are as follows: *3*, cap nut; *4*, valve; *5*, valve stem; *6*, regulating spring; *7*, regulating nut; *8*, exhaust-regulating ring; and *9*, lock ring.

The valve bushing, which acts as a guide for the valve *4*,

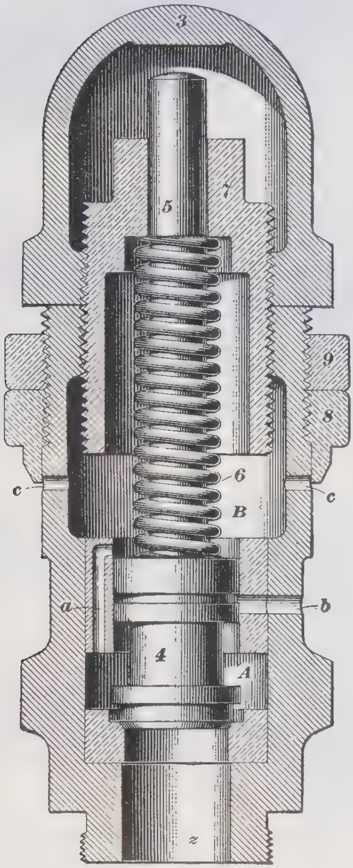


Fig. 30

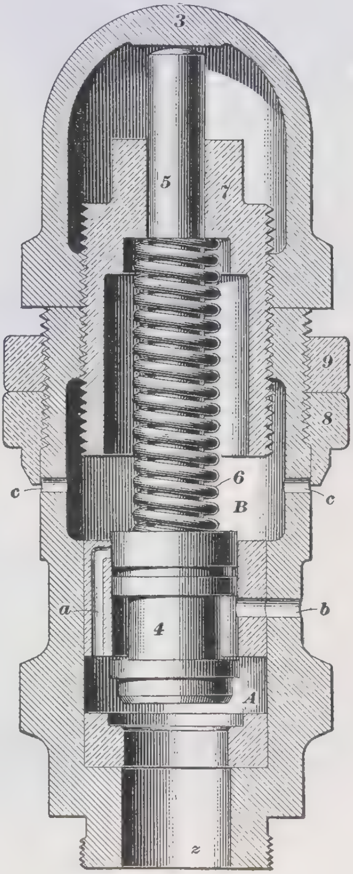


Fig. 31

has six horizontal ports *b* that leads to the atmosphere. The two vertical ports *a* connect the regulating-spring chamber *B* with the valve chamber *A* just before the valve *4* seats; they are closed by the valve before it is fully open. The valve *4* controls the flow of air from the brake cylinder to the atmos-

phere through the ports *b* and from the valve chamber *A* to the regulating-spring chamber *B* through the ports *a*.

The regulating nut *7* is for the purpose of increasing the tension of the regulating spring *6*. Screwing the nut down increases the tension of the spring, and screwing the nut up decreases the tension. The regulating nut also acts as a guide for the valve stem *5*. The cap nut *3* is used to lock the regulating nut *7* in its proper position and also acts as a stop for the valve stem *5*. The cap nut *3* must be removed before the regulating nut *7* can be turned. The exhaust-regulating ring *8* serves to regulate the rate of discharge of air through the ports *c*, of which there are four. These ports allow the air to escape from the regulating-spring chamber to the atmosphere. Screwing the ring *8* down decreases the rate of discharge through the ports *c*, and, consequently, causes the valve *4* to close more promptly; screwing the ring up increases the rate of discharge through the ports *c* and causes the valve *4* to be less prompt in closing. The lock ring *9* is for the purpose of holding the ring *8* in its proper position.

52. Operation.—As previously mentioned, the safety valve is screwed into the opening that connects to port *b* in the seat of the triple slide valve (see Fig. 16). Air from this port enters the safety valve at *z*, Fig. 30, and exerts an upward pressure on the under side of valve *4*. The space under valve *4* is subjected to brake-cylinder pressure at all times except when the triple-slide valve is in emergency position. When the pressure underneath the valve *4* exceeds slightly the pressure exerted by the regulating spring *6*, it forces the valve *4* up to its open position, as shown in Fig. 31. When the valve *4* rises from its seat, a larger area is exposed to the air pressure, and the upward movement of the valve is, therefore, very quick. As the valve *4* moves up it closes the top end of the ports *a*, thus closing the communication between chambers *A* and *B*; at the same time, it uncovers the ports *b*, which open communication between chamber *A* and the atmosphere. This allows brake-cylinder air that flows past valve *4* into chamber *A* to escape to the atmosphere through the ports *b*. As the

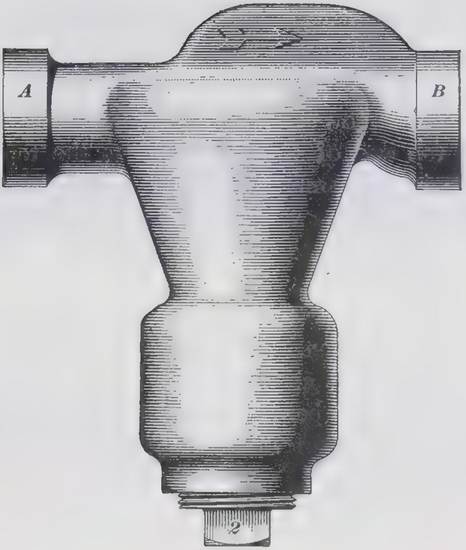


FIG. 32

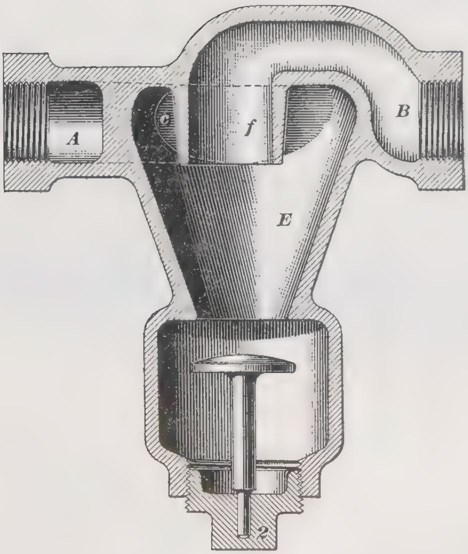


FIG. 33

pressure in the brake cylinder and chamber *A* decreases, the regulating spring *6* gradually moves the valve *4* down toward its seat. This, in turn, gradually closes the ports *b*, thus gradually restricting the flow of air to the atmosphere through ports *b*, until the top end of valve *4* uncovers the top end of the ports *a*. Air from chamber *A* can then pass through the ports *a* to chamber *B* in larger volume than it can escape from chamber *B* through the ports *c*. This causes to accumulate in chamber *B* a pressure that exerts a downward force on the top side of valve *4* and assists the regulating spring *6* in closing valve *4* with a *pop* action. The promptness with which valve *4* will close depends to a certain extent on the rate at which air can escape through the ports *c*, and the rate of discharge of air through the ports *c* can be regulated by the exhaust-regulating ring *8*.

CENTRIFUGAL DIRT COLLECTOR

53. The centrifugal dirt collector, which is now supplied with all complete sets of air-brake equipments, takes the place of the brake-pipe strainer previously furnished. With the brake-pipe strainer there is a tendency for dirt and foreign matter to clog the strainer, thereby restricting the flow of air through it, which frequently results in imperfect operation of the brakes; to clean the brake-pipe strainer, the pipe connections must be broken. With the centrifugal dirt collector no strainer is used; hence, the air passage through the collector remains free and unrestricted at all times. Dirt and foreign matter drop to the bottom of the chamber and are quickly removed without disturbing any pipe connections.

54. Description.—A good idea of the external construction of the centrifugal dirt collector can be obtained from Fig. 32, and its internal construction is plainly shown in Figs. 33 and 34. Air from the brake pipe, on its way to the triple valve, enters the centrifugal dirt collector at *A*, passes through the passage *c*, Fig. 34, down into chamber *E*, Fig. 33, thence up into passage *f*, and out at *B*. The air on its way through

passage *c* receives a whirling motion when it enters chamber *E*, which tends to cause any foreign matter in the air to be carried close to the walls of the chamber. Then, as the air is compelled to rise in order to escape through passage *f*, the foreign matter drops to the bottom of the collector, whence it can be removed by unscrewing the plug *2*.

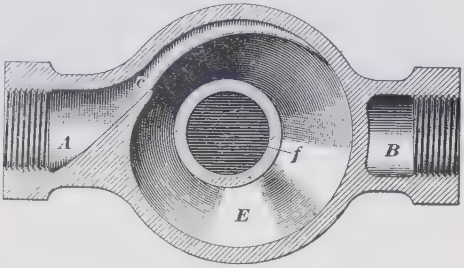


FIG. 34

DISORDERS AND REMEDIES

55. The type L triple valve, like all other triple valves, is subject to disorders that arise from wear and neglect. It is well, therefore, to have a knowledge of these disorders so that, when possible, the proper remedies to correct the troubles may be applied.

56. Undesired Quick Action.—If the triple applies its brake quick action during a service application, it may be due to a dirty triple valve, or, in some cases, to a weak or broken graduating spring. The use of oil or grease to lubricate the slide valve or the seat also tends to cause undesired quick action.

A dirty condition of the triple valve is frequently the cause of a triple valve applying its brake action during a service application. The dirt and gum hold the triple piston so that it cannot move when the brake-pipe pressure is reduced slightly below auxiliary-reservoir pressure; when the difference in pressure is great enough to tear the piston loose, the graduating spring cannot stop its movement and it will go to emergency position, and apply the brake in quick action. The presence of dirt and gum in the triple valve often causes erratic action. Sometimes, it seems to work all right, and at other times it applies quick action.

A weak or a broken graduating spring in an L triple valve is not likely to cause undesired quick action unless the train is short and the triple is dirty and sticky. However, during a service reduction on a long train, the defective spring will permit the triple piston to move the slide valve to full-service position, thereby cutting out the quick-service port; consequently, the quick-service feature of the brakes will be impaired. To remedy this defect, a new spring having the proper tension should be applied.

57. Blow at the Triple-Valve Exhaust Port.—A blow at the triple-valve exhaust port may be due either to a leak from the brake pipe or to one from the auxiliary reservoir. The leak may occur past the slide valve *3,* Fig. 15, the emergency valve *10,* or the gasket *14,* past the gasket between the triple valve and the brake-cylinder head, allowing auxiliary-reservoir or brake-pipe air to leak into passage *C;* or past the graduating valve *7* into port *m.* To determine which of these defects is causing the blow, proceed as follows: First, charge the brake and then close the cut-out cock in the cross-over pipe. If the brake applies, it indicates that brake-pipe pressure is being reduced. This may occur past the emergency valve *10,* the check-valve-case gasket *14,* or the gasket between the triple valve and brake-cylinder head. If the brake does not apply, the blow at the exhaust port is evidently not coming from the brake pipe. Next, open the cut-out cock and apply the brake lightly. If the blow continues, it indicates a leaky slide valve or graduating valve; if the blow ceases, the slide valve and graduating valve are tight. Leave the brake applied for a time. If the blow that occurs when the triple is in release position is caused by a leak from the auxiliary reservoir, the brake will release unless the leak is no greater than the brake-pipe leakage either to the atmosphere or past the triple-piston packing ring. If there is no blow at the triple-exhaust port when the brake is applied, but the brake releases, it is evidently due to a defective triple-valve gasket. An auxiliary-reservoir leak past the slide valve or graduating valve, into the exhaust port, when the brake is applied, will also have a

tendency to cause the brake to release. A leak past the graduating valve into port *m* will cause a blow at the exhaust port, in all positions of the slide valve except emergency position. A brake-pipe leak past the emergency valve, check-valve-case gasket, or the triple-valve gasket, will cause a blow at the triple-exhaust port when the brake is released, but not when it is applied. When the brake is applied with a light application, either of these defects will cause the brakes to apply harder, due to the air in the brake pipe equalizing with that in the brake cylinder. These leaks from the brake pipe will also cause other brakes to apply harder.

58. Check-Valve Leaking.—Defects of the emergency piston and emergency valve in an L triple valve produce the same effects as in any of the other quick-action types of triples, and the remedies for their correction are the same as those recommended for such types of triples. When brake-pipe pressure is reduced below brake-cylinder pressure, a leak past the check-valve *15* will allow air from the brake cylinder to feed into the brake pipe and equalize with the brake-pipe pressure, thus reducing brake-cylinder pressure. In the event of a burst hose or a break in the brake pipe, the brakes will apply quick action, and all brake-pipe air will pass to the atmosphere. If the check-valve leaks, brake-cylinder air will escape past the check-valve into the brake pipe, and thence to the atmosphere, allowing the brake to leak off. A bad leak past the check-valve might retard the service application, as it would allow auxiliary-reservoir air to flow back into the brake pipe while the service reduction was being made.

59. By-Pass Valve Leaking.—In all service applications the by-pass valve *27* cuts off the supplementary-reservoir air from the auxiliary reservoir, as does also the slide valve *3*. Therefore if the by-pass valve leaks, the air from the supplementary reservoir passes into the auxiliary reservoir, and as this is equivalent to combining the volumes of the two reservoirs, a much higher pressure will be obtained in the brake cylinder for a given brake-pipe reduction. The inflow of air from the supplementary reservoir to the auxiliary reservoir

prevents the triple valve from moving to lap position, and the air from these reservoirs continues to pass through the service ports to the brake cylinder until the pressure increases to that at which the safety valve is set. The air escapes at the safety valve until the pressure reduces below that in the brake pipe, when the triple valve will lap. With all air drained from the auxiliary and supplementary reservoir, cap *30*, Fig. 16, may be removed and the by-pass valve *27* taken out for inspection. As it is a rubber-seated valve, a glance will show its condition. If the valve is found to be defective, the old rubber seat should be removed and a new one should be substituted.

The by-pass piston *25* should fit freely but not too loosely in its cylinder, so that in emergency applications the piston will continue to hold the by-pass valve *27* from its seat far enough and long enough to permit a quick and full equalization of supplementary-reservoir, auxiliary-reservoir, and brake-cylinder pressure. If, when an emergency application is made, there is a slow equalization of the supplementary-reservoir, auxiliary-reservoir, and brake-cylinder pressure, it indicates that the by-pass piston fits too loosely in its cylinder.

60. Graduating Valve Leaking.—If the graduating valve leaks auxiliary-reservoir air into port *z*, it will tend to release the brake after partial service applications. If it leaks brake-pipe air into port *l*, when in quick-service lap position, it will feed up the brake-cylinder pressure on that car, causing a tendency to apply all other brakes harder than intended.

61. Quick-Service Ports Stopped Up.—An accumulation of dirt or gum in port *y* in the body of the triple valve and ports *o* and *l* in the slide valve will restrict or entirely prevent the flow of brake-pipe air through these quick-service ports, and thus impair the quick-service operation of the triple valve. As there is a noticeable vibration or buzzing of the check-valve when charging the auxiliary reservoir up from zero, and when initial service reductions are being made, absence of this vibration under the conditions cited, is an indication that these ports are obstructed and that they should be cleaned.

62. Brake Applies but Will Not Release.—The main-piston packing ring in the L triple, as in all other triples, should be practically a perfect fit in its cylinder so as to reduce to a minimum the leakage past it, and also the frictional resistance in moving from one position to another. If the leakage past the triple piston becomes excessive, failure to graduate the service application properly or to permit the prompt release of the brake-cylinder pressure, either graduated or entirely, may result, especially if the triple with the leaky ring is located at or near the rear end of a long train. The remedy for this defect is the application of a new ring properly fitted to the main piston and to the bushing in which it is to move.

If the weather is cold and the brake refuses to release, the triple-valve exhaust port may be frozen up, which would prevent the brake-cylinder air from exhausting when the triple valve moved to release position. If the triple valve moves to release position and air escapes from the exhaust port, but the brake shoes cling to the wheels, it may be due to the fact that some part of the brake rigging is caught on some part of the car, which prevents it from releasing the pressure on the wheels.

Any wrong manipulation of the brake valve when releasing, or a lack of excess pressure that will allow the triple valves to assume graduated-release lap position, will, of course, prevent the brakes from releasing, and may be wrongly attributed to defective triple valves. Such conditions as these will usually cause all the brakes in a train to fail to release.

TYPE K FREIGHT TRIPLE VALVES

DEVELOPMENT OF THE FREIGHT TRIPLE VALVE

1. The original idea of providing a system of brakes that could be applied to all the cars of a train and be under the direct control of the engineer was suggested to George H. Westinghouse in 1866 by a collision between two freight trains. In its beginning, therefore, the brake was regarded merely as a safety device and as such it was brought into use and developed.

The first air brake, namely, the *straight-air brake*, was applied to a train consisting of a locomotive and four cars. On the first run of this train, the engineer, by a prompt application of the brakes, prevented what would likely have been a serious accident had the train been equipped with any other brake then in existence, thus demonstrating the value of the air brake as a safety device. The control of the train equipped with the straight-air brake was so superior to the control that could be obtained by means of any other brake then in use that the idea of using the brake to control a train made up of more than four cars suggested itself. Accordingly, in September, 1869, a six-car Pennsylvania Railroad train was equipped with the air brake, and in November of the same year a ten-car train was thus equipped. As the brake in most general use at that time was a cumbersome "chain" brake applicable to only four- or five-car trains, the success of the air brake in handling ten-car trains

at once made it valuable as a dividend earner. The earning power of the air brake consisted in its ability to handle longer, heavier trains at higher safe speeds than was possible with other brakes then in existence.

2. The adoption of the straight-air brake by a number of the leading railroads, on which it was pressed into general service, eventually brought out the serious defects of the air brake and made a further development of it necessary. This resulted, in 1872, in the invention of the *plain automatic brake*, the triple valve of which made possible the automatic brake of the present day.

The automatic brake was developed during the years 1872 and 1873, and it was so superior to all other forms of brake that it was adopted as the standard for passenger-train service. Up to that time no power brake was in use in freight service, and the attempts to increase the length of freight trains led to numerous accidents and break-in-twos, caused chiefly by lack of proper train control. These accidents led to the belief that the automatic brake could be successfully used in handling long freight trains. To find out whether or not this could be done, the Westinghouse Air Brake Company, in 1882, fitted up a fifty-car train with the plain automatic air brake and took it over the Alleghany Mountains. Tests made on this trial trip clearly demonstrated that the controlling power of this type of brake was sufficient to control the speed of the train even on the heaviest grades.

3. The success of the automatic air brake brought several competitive brake systems into the field, and in 1885 the Master Car Builders' Association appointed a committee to investigate the relative merits of these brake systems as well as to report on the feasibility of controlling a fifty-car freight train by means of a continuous power brake, a point much in controversy at that time. A series of tests with fifty-car trains, known as the "Burlington tests," was begun in 1886 and completed in 1887. The Westinghouse brake and three others were entered in these tests, which clearly demonstrated that none of the brake systems could be

successfully used in every-day service on trains of fifty cars. The Westinghouse brake worked satisfactorily in service applications, but in applying it in emergency the interval between the application of the brake on the first car and last car was so long that the shock caused by the rear cars running into the front cars was terrific.

This necessitated a modification of the plain triple valve for fifty-car freight-train service. Accordingly, in 1887, the quick-action triple valve was brought out. This triple was applied to the fifty-car train, which had been left at Burlington. Tests were made to try out the triples and they were found to be so satisfactory by the railway officials and by the persons conducting the tests that the train was sent on a tour through the Middle West and the East. This tour established the *quick-action brake* as the standard for both freight and passenger service.

4. As will be noted, the straight-air brake and the plain triple valve were developed for passenger service, whereas the quick-action triple valve was developed for freight service, although eventually it was adopted as standard for both freight and passenger service; also, the quick-action triple was designed and developed for use on trains of fifty cars or less, the fifty-car train to be the maximum. From the very beginning, the length, weight, and speed of trains have been limited by the capacity of the brake for the safe and efficient control of the train. The hauling power of the locomotive has always been a step or two in advance of the brake control; consequently, when the length of the train was limited to fifty cars by the brake control, the tonnage of the train was increased to the hauling power of the locomotive by increasing the capacity of the cars. As the capacity of the cars increased, the braking power on the car was necessarily increased in proportion, as was also the hauling power of the locomotive.

The desire to haul trains of more than fifty cars led to the "part-air train" practice, which consisted in using a sufficient number of the head-end brakes to control the train, the rear-

car brakes not being used. This practice was quite successful, and under it the length of the train gradually increased from fifty to eighty and ninety cars. As fifty or fewer than fifty brakes were in use on such trains, the brake system operated without difficulty and engineers soon learned to control the slack of the non-air cars so as to prevent severe shocks and break-in-twos.

5. Next came the rule to increase the percentage of air-braked cars from time to time, until now it is customary to run all-air trains. As sixty- to eighty-car trains have become a fixed practice, and one-hundred-car trains are not uncommon, the air-brake manufacturers have been kept busy experimenting and improving their apparatus in the endeavor to keep the brake up to the requirements of the service. To control an all-air train of eighty to one hundred cars by means of the brake is a vastly different proposition from controlling an eighty-car part-air train. The length as well as the volume of the brake pipe is practically twice that of the original fifty-car train. Therefore, the difficulty experienced in 1887 in emergency applications with the plain automatic brake is now experienced in service applications of the automatic brake; that is, the interval between the application of the brake on the first car and that on the last car is so great in service applications that if a heavy reduction is made without taking due precautions a terrific shock will be caused by the rear cars running in the amount of the slack and colliding with the front cars held by a good application of the brake. In addition, the recoil of the rear cars after the shock, aided by the action of the compressed springs and the application of the brake taking hold on them, tends to snap the train in two. Another serious difficulty, due to the increased brake-pipe volume (which is twice as great as with a fifty-car train) and to the increased back flow of air into the brake pipe from the auxiliaries, due in turn to the slower reduction, is that the time necessary to make a given brake-pipe reduction is doubled. This makes the time of application twice as long, which makes the application of the rear brakes

more uncertain and very materially lengthens the distance required to make a stop. Every second lost at high speed in getting the brake fully applied adds many feet to the length of the stop.

In releasing brakes, the interval between the release of the first brake and the last brake is so great that the brakes on a good portion of the train release and the slack runs out before the brakes on the rear portion release, tending to break the train in two. Also, the brake is slow in releasing, and the rear brakes are especially slow on account of the increased brake-pipe volume to be discharged and the increased size of the auxiliary reservoirs of the large capacity cars that are taking air from the brake pipe during recharge. As the brakes are slow in applying and releasing, both the danger and the time of making a stop and a start are increased.

The difficulty of brake control increased with the length of the train above the limit of fifty cars. However, the brake manufacturers, profiting by their past experience, foresaw the difficulties ahead and bent their energies to improve the brake apparatus so that it would correct the defects of the quick-action brake. Their efforts were along the lines of a uniform application and a uniform release and recharge of all brakes, for if that object could be attained the brake would safely and efficiently control trains of any practical length. The result of the experiments and tests conducted resulted in an improved type of freight triple valve called the *type K triple valve.*

DESCRIPTION AND OPERATION

DESCRIPTION OF TYPE K FREIGHT TRIPLE VALVE

6. The **Type K freight triple valve** is used only in freight service and, as already stated, was designed to meet the conditions brought about by the increase in train speeds, in length of trains, and in car capacities that obtain at the present time. It is made in two sizes, which can be distinguished by the mark *K–1* or *K–2* on the side of the valve body. The K–1 triple is used with 6- and 8-inch brake cylinders, and the K–2 triple with 10-inch brake cylinders. Another difference between the K–1 and K–2 triples is that the K–1 triple has but two bolt holes while the K–2 triple has three bolt holes in the reservoir flange. The K–1 triple and the F–36 triple are made to bolt to the same reservoir; the K–2 triple and the H–49 triple are to bolt to the same reservoir.

The old type H triple valve that is in general use in freight service was designed for maximum trains of fifty cars of 30-ton capacity. The practice of running trains of greater length and weight necessitated a quicker serial action of the brake in service applications, a retarded release of the head brakes, and a uniform recharge of the head and rear auxiliaries to permit the train to be handled successfully. The type K triple valve embodies these additional features as well as all the features of the type H triple.

7. In Figs. 1 and 2 are two side views of the K triple valve that show plainly its outward appearance. Fig. 3 is a vertical section through the valve. It shows half the triple-valve case, with the movable parts in the position they occupy when the triple is in release position, as well as most of the ports and passages.

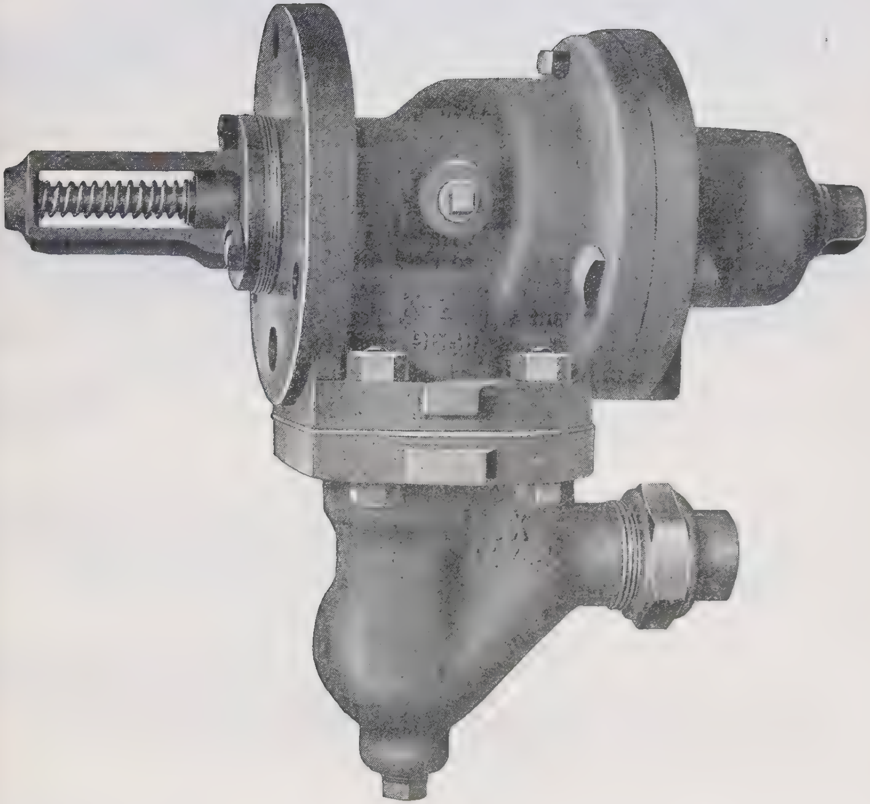


Fig. 1

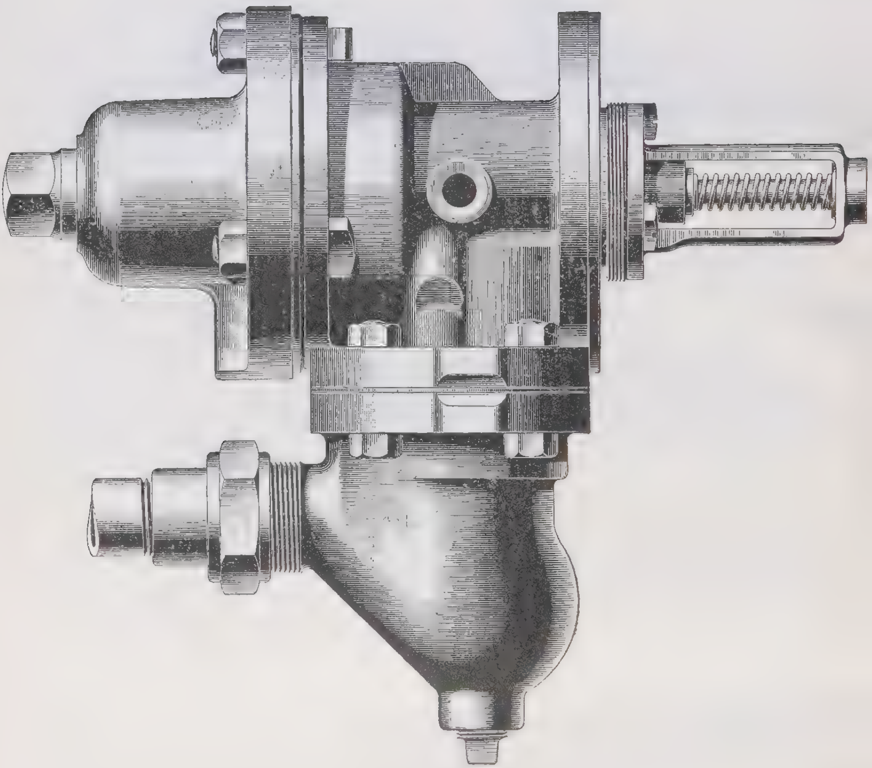


Fig. 2

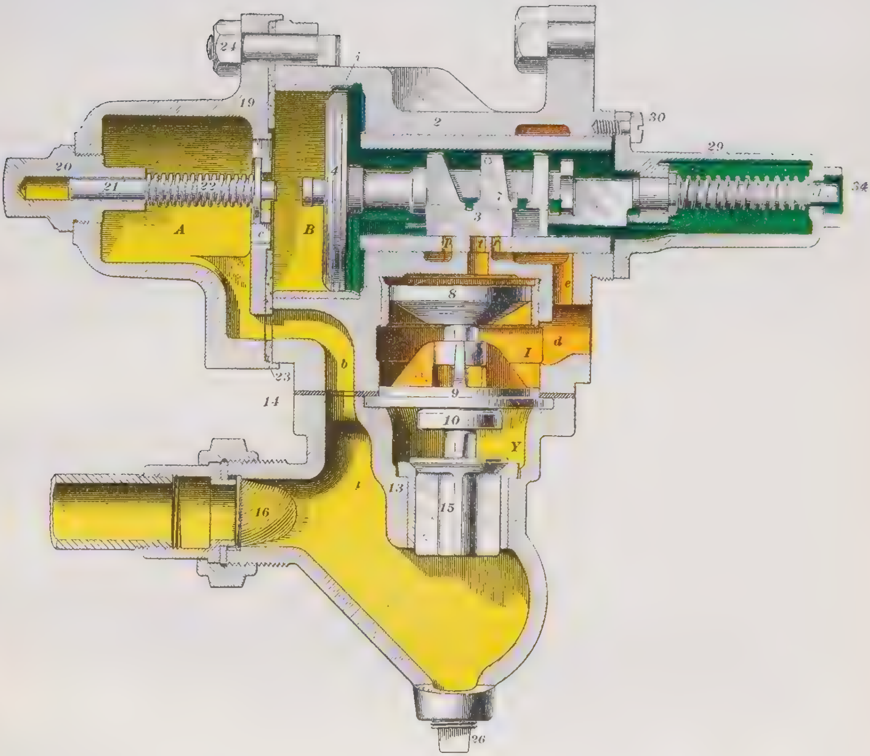


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Fig. 3

Fig. 4 shows two views of the slide valve. View (*a*) shows the top of the slide valve that forms the seat for the graduating valve, and view (*b*) shows the face of the slide valve. These views represent the slide valve as transparent in order to bring out the relations of the ports, passages, and cavities in the valve.

Fig. 5 is a view of the face of the graduating valve *7*, showing the cavity *v* in the face of the valve. The graduating valve *7* is moved back and forth on the back of the slide valve.

Fig. 6 is a view of the slide-valve seat, showing the ports *p*, *r*, *t*, and *y*.

Fig. 7 is a view of a portion of the triple-valve body so sectioned and broken away as to show how port *y* leads from chamber *Y* to the slide-valve seat.

Figs. 8 to 14, inclusive, are conventional views that show the various ports, passages, cavities, and movable parts on the same plane. Owing to the number of ports in the K triple and to their locations, it is difficult to illustrate the operation of the triple valve by means of true sectional views. Therefore, these conventional views are given to assist in explaining the operation of the triple as well as to simplify the tracing of the flow of air through it. They are not intended to represent the actual appearance of the triple valve.

8. Referring to Fig. 3, the names and numbers of the parts are as follows: *2*, valve body; *3*, slide valve; *4*, triple piston; *6*, slide-valve spring; *7*, graduating valve; *8*, emergency piston; *9*, emergency-valve seat; *10*, emergency valve; *13*, check-valve case; *14*, check-valve-case gasket; *15*, check-valve; *16*, strainer; *19*, cylinder cap; *20*, graduating-stem nut; *21*, graduating stem; *22*, graduating spring; *23*, cylinder-cap gasket; *24*, cylinder-cap bolt and nut; *26*, drain plug; *29*, retarding-device body; *30*, retarding-device screw; *31*, retarding stem; *32*, retarding-spring collar; *33*, retarding spring; and *34*, retarding-stem pin.

9. Duty of the Movable Parts.—The movable parts of the triple valve are the triple piston *4*, the slide valve *3*, the graduating valve *7*, the emergency piston *8*, the emergency

valve *10*, the check-valve *15*, the graduating stem *21* and spring *22*, the retarding-device stem *31*, and the spring *33*. The duty of the triple piston *4* is to control the movement of the slide valve *3* and the graduating valve *7* as well as to open and close the feed groove *i*.

The slide valve *3* controls the flow of air between the auxiliary reservoir and the brake cylinder, between chamber *Y* and the auxiliary, between the brake cylinder and the atmosphere, and between the auxiliary and the chamber above the emergency piston. The duty of the slide-valve spring is to hold the slide valve firmly on its seat and thus prevent foreign matter from getting under the valve when there is no air pressure in chamber *C*.

The graduating valve *7* measures the air admitted from the auxiliary reservoir into the brake cylinder during service applications of the brake; also, its cavity *v* connects ports *o* and *q* in the top of the slide valve and completes the connection for chamber-*Y* air to pass into the brake cylinder in quick-service position of the triple valve.

The duty of the graduating stem *21* and spring *22* is to prevent the triple piston from moving past full-service position during a service application of the brakes when only a few cars are handled in a train, or past quick-service position when conditions require it.

The duty of the retarding stem *31* and spring *33* is to govern the movement of the triple piston and the slide valve between release and retarded-release position. When the pressure on the brake-pipe side of the triple piston exceeds that on the auxiliary-reservoir side by about 3 pounds, the tension of the retarding spring will be overcome and the triple piston and slide valve will be moved to retarded-release position; as the auxiliary pressure increases and the difference of pressures on the two faces of the piston decreases, the retarding stem and spring will return the triple piston, slide valve, and graduating valve to their full-release position.

10. The duty of the emergency piston *8* is to unseat the emergency valve during an emergency application of the

brakes. It is made to fit loose enough in its bushing to allow the brake-pipe air from chamber *Y*, after passing through port *y*, the slide valve, graduating valve, and port *t* into the chamber above the emergency piston, to pass by the piston and enter the brake cylinder without forcing the piston downwards.

The duty of the emergency valve *10* is to prevent brake-pipe air from passing through chamber *Y* and chamber *I* into the brake cylinder, except when unseated by the emergency piston during an emergency application of the brakes. It is provided with a rubber seat better to prevent leakage past it. The check-valve *15* prevents brake-cylinder air from passing to the brake pipe whenever brake-cylinder pressure is the greater; also, it allows brake-pipe air to pass to chamber *Y* when the pressure in that chamber is reduced by air passing through port *y* when the triple valve is in quick-service or full-release position.

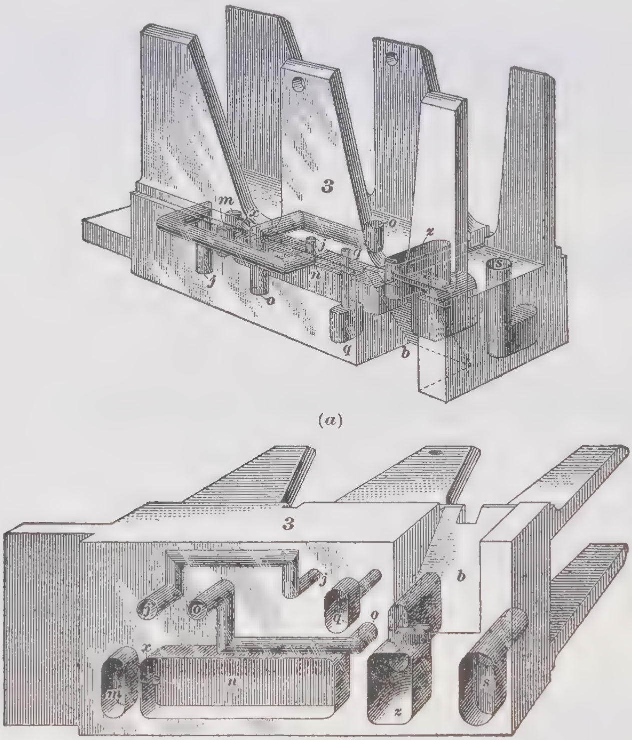
11. Duty of Ports and Cavities in Slide Valve and Seat.—Referring to Figs. 3, 4, 5, and 6, it will be seen that service port *z* extends through the slide valve; it conveys auxiliary-reservoir air to the brake cylinder through port *r* in the slide-valve seat when the valve is in service position. Ports *z* and *r* fully register when the slide valve is in full-service position, but only partly register when in quick-service position. The opening of the upper end of port *z* is controlled by the graduating valve.

Cavity *n* is the exhaust cavity, and when the slide valve is in full-release position it connects ports *p* and *r* in the slide-valve seat and allows the air from the brake cylinder to pass freely to the atmosphere. In retarded-release position, it registers with port *r* and conveys brake-cylinder air to groove *m* in the face of the slide valve by way of the restricted passage *x* in the interior of the slide valve.

Passage *x* in the interior of the slide valve connects the cavity *n* with the groove *m*. In retarded-release position, the air, in exhausting from the brake cylinder, has to pass through port *x* on its way to the exhaust port. Port *x* is made small

so as to retard the escape of brake-cylinder air in retarded-release position sufficiently to make the head brakes on a long train release at about the same instant that the rear brakes release through the cavity *n* in the slide valve.

The emergency port *s* extends through the slide valve and conveys auxiliary-reservoir air to the brake cylinder during



(*a*)

(*b*)

Fig. 4

emergency applications, at which time it registers with port *r* in the slide-valve seat.

Port *o* extends directly through the slide valve and conveys brake-pipe air from port *y* in the slide-valve seat to cavity *v* in the graduating valve when both valves are in quick-service position.

Port *q* extends through the slide valve and conveys brake-pipe air from cavity *v* in the graduating valve to port *t* in the slide-valve seat, with which it registers in quick-service position.

12. The feed groove *i* in both the K–1 and the K–2 triple valve is the same size as that in the F–36 triple valve. Experience has shown this to be the proper size of feed groove to charge the auxiliary reservoir of an 8-inch brake cylinder in a proper manner. At the same time it is not so large as to permit an excessive amount of auxiliary air to feed back into the brake pipe during an application of the brakes before the feed groove is closed. The K–2 triple valve, however, is used with 10-inch brake cylinders; it must therefore have an additional charging port to enable it to take care of the enlarged capacity of the auxiliary that goes with the 10-inch brake cylinder. Port *j* is provided in the slide valve of the K–2 triple for that purpose. It conveys brake-pipe air from chamber *Y* through port *y* to the auxiliary reservoir when the slide valve is in full-release position, thus assisting in promptly recharging the auxiliary reservoir. The combined area of groove *i* and port *j* is just sufficient to charge the auxiliary reservoir of a 10-inch brake cylinder in practically the same time that feed groove *i* will charge the auxiliary of an 8-inch brake equipment.

The removed corner *b* extends diagonally across the corner of the slide valve. It is provided so that port *t* in the valve seat will be uncovered and thus allow auxiliary-reservoir air to pass to the emergency piston and operate the brake quick action when the slide valve is in emergency position.

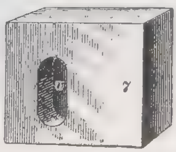


FIG. 5

Cavity *v* in the graduating valve, Fig. 5, connects ports *o* and *q* in the top of the slide valve to allow brake-pipe air to pass between these two ports on its way to the brake cylinder when the slide valve and the graduating valve are in quick-service position.

13. Port *t*, Fig. 6, leads from the face of the slide-valve seat to the space above the emergency piston. It is uncovered

by the removed corner *b* in the slide valve and conveys auxiliary-reservoir air to this space to operate the emergency pis-

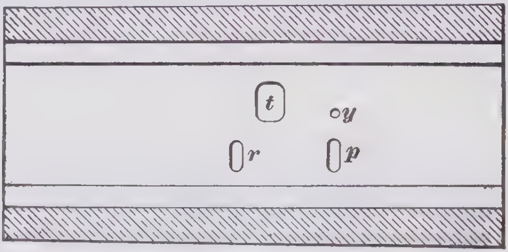


Fig. 6

ton during emergency applications. In quick-service position, brake-pipe air passes from chamber *Y* through the slide

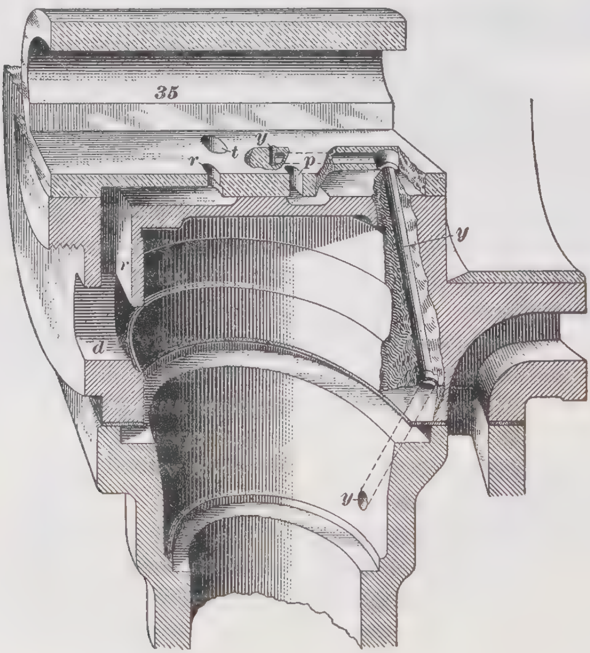


Fig. 7

valve and graduating valve and port *t* to the space above the emergency piston and then past the piston into the

brake cylinder. The emergency piston is not forced down in this position because the air is not supplied through port *y* at a rate greater than it can pass by the emergency piston into the brake cylinder.

Port *y* in the slide valve seat, Fig. 7, leads to the check-valve chamber *Y* and supplies brake-pipe air to the brake cylinder when the slide valve is in quick-service position and to the auxiliary reservoir when the valve is in full-release position.

Port *r* in the slide-valve seat is used in all positions of the triple except lap position. In full-service, quick-service, and emergency positions, it conveys auxiliary-reservoir air to the brake cylinder; in full-release and retarded-release positions, it conveys brake-cylinder air to cavity *n* in the slide valve on its way to the atmosphere.

14. The retarding device of a K triple when the triple is attached to an auxiliary reservoir extends into the auxiliary reservoir and cannot be seen. The triple then looks like an H triple and can be distinguished from it only by means of the letter K cast on the body of the valve, Fig. 1, and the fin-like lug that is cast on the top of the valve body; these serve as distinguishing marks for the K triples.

The emergency parts of a K triple valve are exactly the same as those of an H triple and are interchangeable with them. The service parts differ somewhat. The slide valve, seat, and graduating valve of the K triple are different from those of the H triple; also, the K triple has a retarding device and its valve body and check-valve case differ from the H triple valve.

In an emergency application of the brakes, the K triple valve operates exactly the same as the H triple. In service applications, however, the K triple valve includes the quick-service feature. Also, in releasing brakes it includes the retarded- or uniform-release, and the uniform-recharge features that the H triple does not possess.

15. Quick-Service Feature.—The object of the **quick-service feature** is to quicken the serial application of

the brakes on long trains, so as to reduce the interval between the application of the first and the last brakes. This is accomplished by each triple valve venting brake-pipe air momentarily through a restricted passage into the brake cylinder, thus producing at each triple a slight brake-pipe reduction that is quickly transmitted from car to car throughout the brake pipe in a manner similar to a quick-action application. With a train of all K triple valves, this feature reduces the time of application about one-half that required by H triples; applies the brakes more uniformly throughout the train; insures the application of all the brakes with light brake-pipe reductions; gives a higher brake-cylinder pressure, increasing the brake-cylinder pressure about 1 pound on equalization with standard piston travel; and effects a considerable saving in air. By venting brake-pipe air into the brake cylinders, the K triple reduces the time of discharge of brake-pipe air from the brake-valve exhaust for a given reduction about half the time necessary with H triples.

The quick-service feature operates only on trains of such lengths that the volume of the brake pipe is too large for brake-pipe pressure to be reduced at the proper rate through the brake-valve exhaust. If the reduction can be made at the proper rate, as with short trains, the quick-service feature automatically becomes inoperative.

16. Retarded- or Uniform-Release Feature.—To release the brakes, main-reservoir pressure is thrown into the brake pipe, so as to cause a wave of pressure to flow from the head end toward the rear. The head triples feel the impulse first and move to release position quite an interval before the rear triples. They cannot be prevented from going to release position first; therefore, the only way to get a uniform release of the brakes throughout the train is to restrict the exhaust port of the head triples and retard the exhaust of brake-cylinder air sufficiently to permit the head and rear brakes to let go at about the same instant.

The object of the **retarded-** or **uniform-release** feature is to retard the exhaust from the brake cylinders of the head

brakes so as to make the release of the brakes more uniform throughout the train. With H triples, the head brakes begin to release first. After a 15-pound reduction on an eighty-car train, they fully release 30 seconds before the rear brakes. With K triples, the head triples move to release position first, but about the first thirty triples are forced past normal release to retarded-release position and their brake cylinders release through a restricted port; only the rear triples move to normal release position and exhaust through the full size of the exhaust port. The relative sizes of the restricted and normal exhaust ports are such that the head and rear triples exhaust their brake cylinders in approximately the same time; consequently, the brakes release uniformly throughout the train and in less than half the time required by H triples. This results in much smoother operation and greatly reduces the shocks and consequent break-in-twos, slid flat wheels, and damage to equipment and lading.

To move a triple valve to retarded-release position, the brake-pipe pressure must be raised about 3 pounds above auxiliary-reservoir pressure. On a long train it has been found impossible to obtain this difference of pressure beyond about thirty cars back of the engine; consequently, the triple valves beyond that point do not go to retarded-release position.

17. Uniform-Recharge Feature.—The object of the **uniform-recharge feature** is to increase the rate of rise of brake-pipe pressure in the rear end and to make the auxiliary reservoirs throughout the train recharge at approximately the same rate, thus insuring a more prompt action of the rear-end brakes and preventing the head brakes from reapplying when the brake valve is moved to running position. When H triple valves are used, all the feed-grooves are of the same size; consequently, the head auxiliaries overcharge on account of the higher brake-pipe pressure they are subjected to with the brake valve in release position. Thus, when the brake valve is moved to running position, the pressure in the head end of the brake pipe drops until it equalizes with

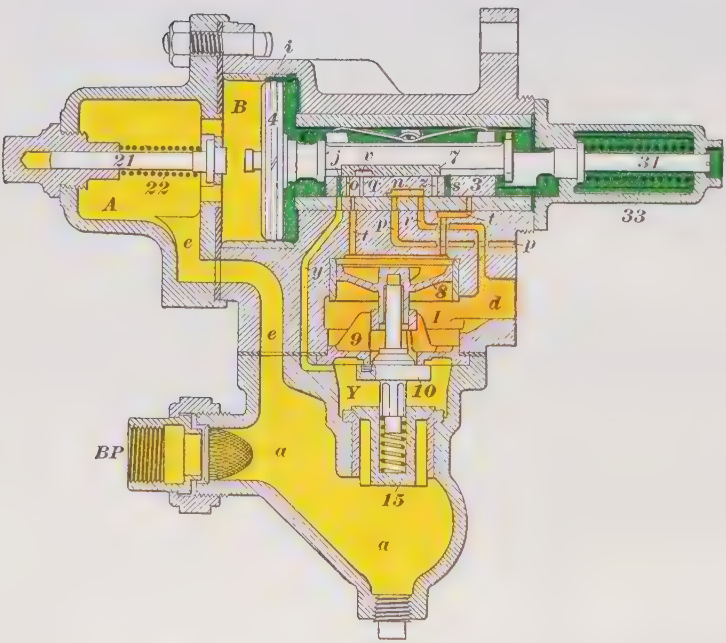
the lower pressure in the rear end of the brake pipe and the head-end brakes reapply.

With K triple valves, the feed groove *f* (located in the ridge on the back of the triple piston) through which the auxiliary charges when the triple is in retarded-release position, is about half as large as the feed groove *i*, used when the triple is in normal release position; consequently, the head-end auxiliaries charge through a restricted opening that compensates for the higher brake-pipe pressure in the head end and permits more of the air passing into the brake pipe to flow to the rear end of the train, charging the brake pipe to a higher pressure and releasing and recharging the brakes more promptly.

In releasing the brakes, the pressure in the head end of the train *rises much more rapidly* and to a higher pressure than in the rear end. This is due to the head end being nearer the supply of air, to the frictional resistance offered to the flow of the air by the brake pipe, and to the fact that each triple valve starts to recharge its auxiliary the moment it moves to release position. The primary object of the uniform-recharge feature, therefore, is to *increase the rate of rise of brake-pipe pressure toward the rear end*, thereby obtaining a quicker release and recharge of the rear brakes; this results in shortening the time necessary to release all brakes, in a more uniform release of all brakes, and in a more uniform and quicker recharge of all auxiliaries.

OPERATION OF TYPE K FREIGHT TRIPLE VALVES

18. Full-Release and Charging Position.—When the engineer's brake valve is placed in full-release or running position, the air entering the brake pipe raises the pressure in chamber *B* above that in the slide-valve chamber *C* and the auxiliary reservoir, and moves the triple piston, slide valve, and graduating valve to the right. If brake-pipe pressure in chamber *B* does not exceed the auxiliary-reservoir pressure in chamber *C* by 3 pounds, as is usually the case on all cars back of the thirtieth car of a long train, the retarded-release stem and spring will stop the triple piston and slide valve



58B-I L T 26C, 178B, 291 § 12 FIG. 8

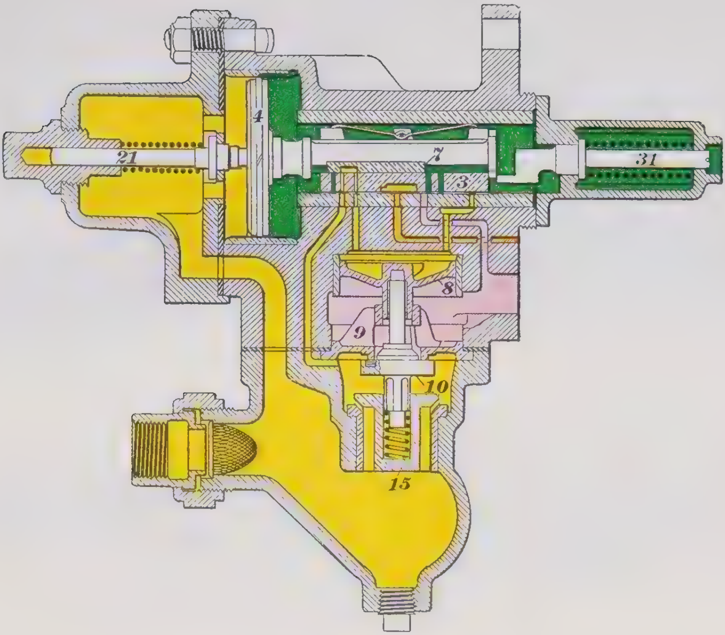


Fig. 9

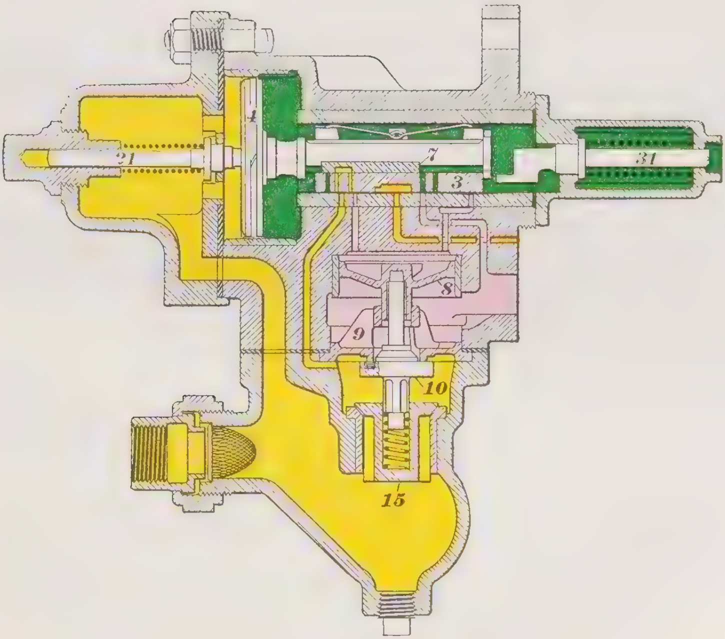


Fig. 10

in *full-release position*, as shown in Fig. 8. When in this position, the feed groove *i* in the triple-piston bushing is uncovered and brake-pipe air passes through it past the triple piston and charges the auxiliary reservoir; also, port *j* in the slide valve registers with port *y* in the slide-valve seat and conveys air from chamber *Y* to the slide-valve chamber, thus assisting in charging the auxiliary reservoir, the check-valve *15* being unseated by brake-pipe pressure while air is passing through port *y* to the auxiliary reservoir.

Cavity *n* in the slide valve fully connects ports *r* and *p* so that brake-cylinder air can escape freely to the atmosphere.

Air flows from the brake pipe through feed groove *i* into the auxiliary until the pressures equalize and the auxiliary reservoir is fully charged. Air flows through port *y* into the auxiliary until the pressures are equalized near enough for the check-valve spring to seat the check-valve, after which the auxiliary charges through the feed groove *i* alone.

19. Quick-Service Position.—When a service reduction is made in brake-pipe pressure at the brake valve, the pressure in chamber *B*, on the brake-pipe side of the triple piston, is reduced faster than auxiliary-reservoir pressure can reduce through the feed groove *i*. This produces a difference of pressure on the two faces of the piston, and when this difference becomes about 2 pounds per square inch, the auxiliary-reservoir pressure in chamber *C*, being the greater, forces the piston forwards to application position, taking the graduating valve *7* with it and closing the feed-groove *i*. This movement of the triple piston first causes the graduating valve to uncover port *z* and to connect ports *q* and *o* in the back of the slide valve through cavity *v*; then the shoulder on the triple-piston stem engages the slide valve and moves it to application position. If the difference in pressure on the two faces of the triple piston is not sufficient to compress the graduating spring *22*, these parts will be held in *quick-service position*, as shown in Fig. 9

In this position, the triple piston is close to or against the graduating stem but does not compress the graduating spring.

The slide valve cuts off the connection between ports *r* and *p* so that brake-cylinder pressure cannot pass to the atmosphere; port *z* in the slide valve partly registers with port *r* in the seat, and ports *q* and *o* in the face of the slide valve register, respectively, with ports *t* and *y* in the seat. Auxiliary-reservoir air now flows through ports *z* and *r* into the brake cylinder and applies the brakes; also, brake-pipe pressure, raising check-valve *15*, passes through ports *y* and *o* to cavity *v* in the graduating valve, then through ports *q* and *t* to the chamber above the emergency piston, from which place it can pass the emergency piston, which fits loosely in its cylinder, to the passage *d* and the brake cylinder. Ports *y*, *o*, and *q* are so restricted that the flow of air through them, when connected, is not great enough to raise sufficient pressure above the emergency piston to force it down and cause an emergency action of the triple, but the air that passes to the brake cylinder reduces the brake-pipe pressure locally at each triple valve just enough to cause the next triple valve to operate promptly. This local reduction acts to transmit quickly and uniformly the brake-valve reduction from car to car in a manner similar to the serial action during an emergency application, only the amount of the reduction is not so great. As a result of this serial action, the time interval between the operation of the first and last brakes on a long train is only about half for the K triples that it is for the H triples; also, with a long train of K triples, the time required for the air to exhaust from the brake-pipe exhaust valve of the brake valve for a given reduction will be only about half the time required with a train of H triples. The venting of brake-pipe air into the brake cylinder results in a pressure on equalization that is about 1 pound higher.

After the triple piston has moved the slide valve to quick-service position, the slide valve does not move again until the brake is released or a sufficient reduction is made in brake-pipe pressure to move it to full-service or emergency position; the graduating valve controls the quick-service ports *o* and *q* in the slide valve, so that they are opened each time the graduating valve opens the service port *z* and closed

each time the piston moves the graduating valve to lap position.

The quick-service feature of the K triple valve operates only when the brake-pipe reduction is being made at less than the proper rate, as when the train is long. With a short train, the brake valve can reduce brake-pipe pressure as fast as is necessary, and the local reduction is not desirable; hence, under such conditions, the quick-service feature automatically goes out of service by the triple valve going to full-service position.

The tendency of the triple to produce quick action during a service application is guarded against by proportioning the valves and locating the ports so that the service port *z* will not fully register with port *r* while port *o* is connected to port *y*, and any movement tending to compress the graduating spring will increase the opening through port *z* and decrease the opening through port *y*. This gradually increases the rate of discharge from the auxiliary reservoir, and decreases the rate of discharge from the brake pipe, until port *z* is opened its full amount and port *y* is entirely closed.

20. Full-Service Position.—The strength of the graduating spring *22* is such that when the reduction in the brake pipe is being made at the proper rate, the difference in pressure on the triple piston will be great enough to compress the graduating spring sufficiently to permit the slide valve to assume *full-service position*, as shown in Fig. 10. Thus, as the quick-service feature is not needed, it is automatically cut out of commission by the ports *o* and *q* being moved out of register with ports *y* and *t*.

When the brake-pipe reduction is slower than it should be, as when the train is long, or during moderate reductions, the service port *z* is opened sufficiently to prevent a difference of pressure from being formed that would compress the graduating spring *22*.

With the triple valve in full-service position, ports *z* and *r* register fully. The quick-service port *y* is blanked by the

slide valve so that no brake-pipe air can pass to the brake cylinder through port *y*. The local reduction of brake-pipe pressure at each triple valve is thus prevented because the reduction is being made as fast as desirable at the brake valve, and any local reduction would cause undesired quick action of the brakes. However, the brakes will apply promptly because the service port *z* is fully open and auxiliary pressure reduces at the same rate as brake-pipe pressure.

21. Lap Position.—The lap position assumed by the triple valve from quick-service position is different from the lap position it assumes from full-service position, as will be seen in Figs. 11 and 12. This is due to the fact that the slide valve is not moved when the piston moves the graduating valve to lap the service ports.

The triple valve is held in service position as long as the brake-pipe reduction continues. When it ceases, auxiliary-reservoir air still flows into the brake cylinder until auxiliary pressure is reduced below brake-pipe pressure sufficiently to cause the triple piston to be moved toward release position and the shoulder of the stem comes in contact with the slide valve. The difference in pressure necessary to move the piston and graduating valve is not sufficient to overcome the friction of the slide valve, so that further movement of the piston is stopped by the slide valve.

When the piston starts to lap position from quick-service position, the parts come to rest in quick-service lap position. In this position the graduating valve *7* closes the top end of ports *o* and *z* so that no more air can pass to the brake cylinder either from the auxiliary reservoir through port *z* or from the brake pipe through port *y*.

If the triple valve is in full-service position when the reduction of brake-pipe air at the brake valve ceases, it will assume lap position in the manner just explained, but the triple piston will be assisted in its movement to lap position by the graduating spring *22*, which was slightly compressed, and the piston will be stopped in *full-service* lap position, instead of in *quick-service* lap position.

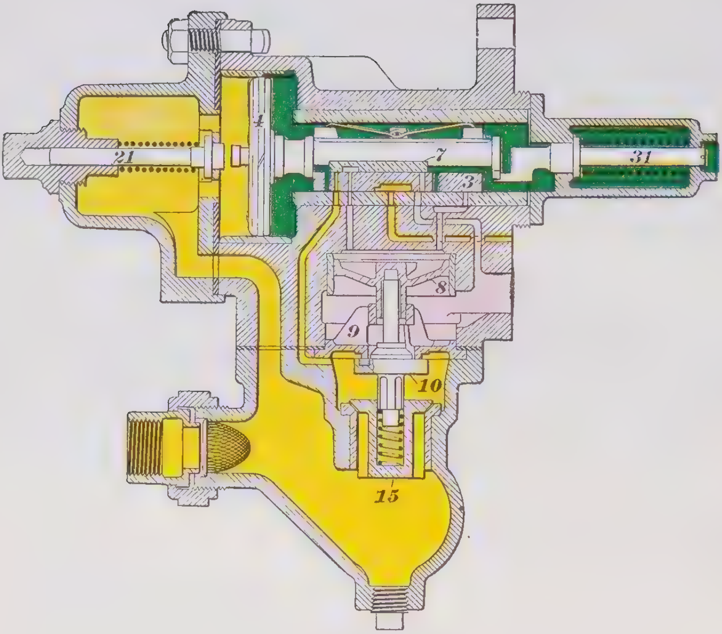


FIG. 11

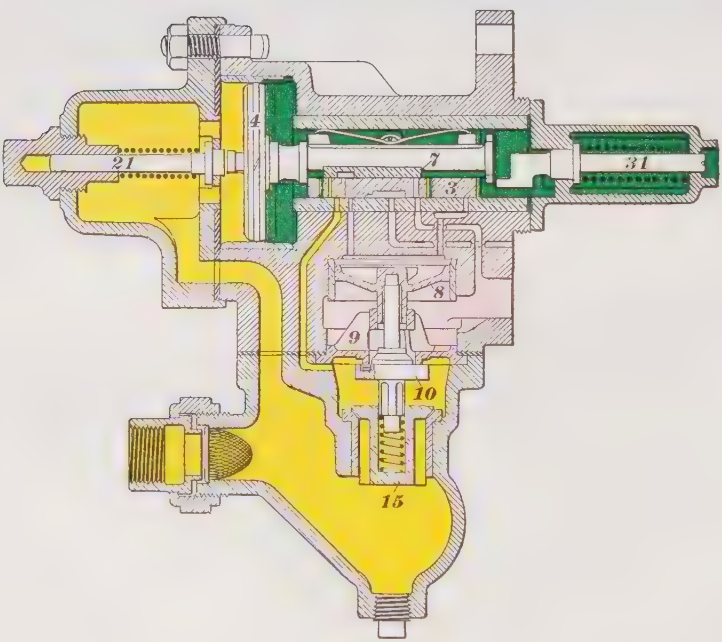


 FIG. 12

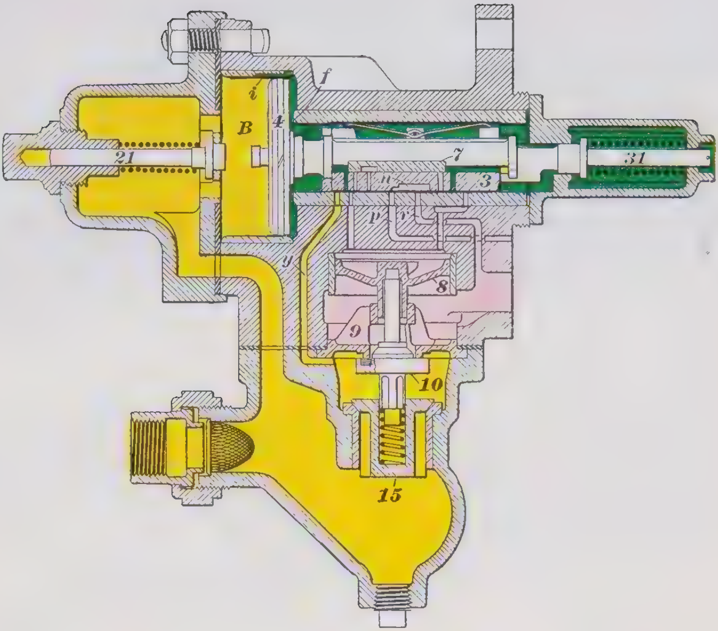


Fig. 13

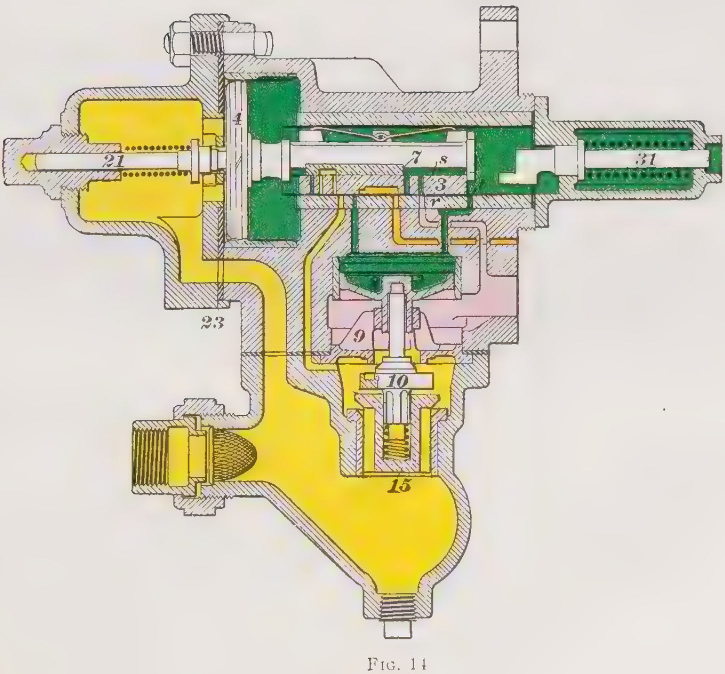


Fig. 14

22. Second Reduction During a Service Application.—When a second reduction is made by the engineer's brake valve, the triple piston will move from lap to service position and take the graduating valve with it. The slide valve, being already either in quick-service or in full-service position, will not move. This will again open the service ports and the auxiliary-reservoir air will pass into the brake cylinder. When the brake-pipe reduction has ceased, and the auxiliary-reservoir pressure in chamber *C* has reduced below the brake-pipe pressure in chamber *B*, the triple piston and graduating valve will be moved to lap position in the same manner as after the first reduction. These reductions may be continued until the brake is fully applied by the auxiliary-reservoir and brake-cylinder pressure equalizing. When this occurs, the triple piston will remain in service position and will not return to lap position. A further reduction in brake-pipe pressure will cause the piston to move to emergency position, but will not apply the brake harder and will only be a waste of brake-pipe air. A brake-pipe reduction of about 20 pounds from a pressure of 70 pounds will give equalization.

23. Retarded-Release Position.—If, when releasing the brakes, the brake-pipe pressure in chamber *B* is 3 pounds or more in excess of the auxiliary-reservoir pressure in the slide-valve chamber *C* of the triple valve, as is usually the case on the head cars of a train, the triple piston, instead of stopping when it strikes the retarding stem *31*, will compress the retarding spring *33* and move to *retarded-release position*, Fig. 13, taking the slide and graduating valves with it.

When in this position, the ridge on the back of the triple piston is against the end of the slide-valve bushing, with which it makes an air-tight joint except at the feed groove *f*. Brake-pipe air from chamber *B* therefore passes the triple piston through the feed groove *i*, thence through feed groove *f* to chamber *C* and the auxiliary reservoir. As the feed groove *f* has only about half the area of feed groove *i*, the auxiliary reservoir will be recharged much more slowly

when the triple valve is in retarded-release position than when it is in full-release position.

Port *y* in the slide-valve seat is covered by the slide valve in retarded-release position, so that the auxiliary reservoir can get no air from that source.

Cavity *n* in the slide valve registers with port *r* in the seat, and groove *m* in the slide-valve face, Fig. 4 (*b*), registers with the exhaust port *p*, and since cavity *n* and the groove *m* are connected by the restricted passage *x* through the body of the slide valve, brake-cylinder air will escape very slowly to the exhaust port and the atmosphere. When the difference of pressure between the brake-pipe and auxiliary reservoir is less than the tension of the retarded-release spring by an amount sufficient to compensate for the friction of the parts, the triple piston and slide valve will be moved back to full-release position by the spring.

24. Emergency Position.—When a heavy and sudden reduction of brake-pipe pressure is made by the brake valve or in some other way, the pressure on the brake-pipe side of the triple piston also reduces suddenly and the greater auxiliary-reservoir pressure forces the triple piston forwards to *emergency position*, Fig. 14. The triple piston moves the slide valve *3* and the graduating valve *7* with it. The graduating spring *22* is compressed and the triple piston is forced tightly against gasket *23*, making an air-tight joint with it. When the slide valve *3* is in this position, the service ports do not register. The removed corner *b* of the slide valve, Fig. 4, is over port *t* in the slide-valve seat, so that auxiliary-reservoir air flashes down on top of the emergency piston *8* faster than it can pass by the piston, and the piston *8* therefore is forced down and unseats the emergency valve *10*. This allows the air in chamber *Y* to escape into the brake cylinder; then, brake-pipe pressure raises the check-valve *15* and brake-pipe air flashes into the brake cylinder. This creates a local reduction of brake-pipe pressure at the triple valve that causes the next triple valve to apply quick action, and so on throughout the train. The emergency port *s* in

the slide valve, Fig. 4, which is never covered by the graduating valve, now registers with port *r* in the slide-valve seat and conveys auxiliary-reservoir air to the brake cylinder. The check-valve *15* seats about the time that brake-pipe and brake-cylinder pressures have nearly equalized, and it thus prevents the escape of brake-cylinder air to the brake pipe. The emergency valve *10* is forced to its seat by the check-valve spring when the brake-cylinder and auxiliary-reservoir pressures have nearly equalized. The joint made by the triple piston being forced against the gasket *23* prevents any air that may pass by the triple-piston packing ring from escaping into the brake pipe.

DEFECTS AND CARE OF EQUIPMENT

DEFECTS OF THE K TRIPLE VALVE

25. Brake Applies Quick Action.—If the triple valve applies its brake quick action during a service application it may be due to: (1) a dirty condition of the triple valve or (2) to a weak or broken graduating spring *22*.

1. *Dirty Triple Valve.*—A dirty triple valve is the most frequent cause of a brake applying quick action during a service application. The gum and dirt will hold the triple piston when the first brake-pipe reduction is made, but when the difference of pressure between the auxiliary and brake pipe is great enough to loosen the piston from the gum and dirt, it will travel rapidly to emergency position and apply its brake quick action, and the heavy local reduction of brake-pipe pressure at this triple valve will cause the others to apply quick action also, or at least cause them to apply in full.

2. *Weak or Broken Graduating Spring 22.*—A weak or broken graduating spring *22* will cause trouble on a short train but may not cause any trouble on a long one. When the train is short, the brake-pipe volume is smaller than when the train is long, and its pressure can reduce through the brake-pipe exhaust port at the brake valve faster than

auxiliary-reservoir pressure can be reduced through the service port *z* in the triple valve. When this difference of pressure is great enough, auxiliary-reservoir pressure will force the triple piston and slide valve to emergency position and apply the brakes quick action. On a long train, where the brake-pipe volume is greater, brake-pipe pressure may not reduce faster through the brake-pipe exhaust port at the brake valve and the quick-service ports in the triple valves than auxiliary-reservoir pressure can reduce through the service port *z* in the triple valve; consequently, a weak or broken graduating spring may cause no trouble. But, if the train is not very long, a triple valve with a weak or broken graduating spring may assume full-service position that would otherwise assume quick-service position.

26. Blow at Triple-Valve Exhaust Port.—A blow at the triple exhaust port may be caused by either a brake-pipe or an auxiliary-reservoir leak. The brake-pipe leak may be due to a defective emergency valve or a leak past the gasket *14*. An auxiliary leak may be caused by a leaky slide valve *3*, a leaky gasket *25* allowing air to feed into passage *d*, Fig. 3, or a leaky auxiliary tube *b*.

To test for the leaks, proceed as follows: With the brake system charged, close the cut-out cock in the cross-over pipe, and if the brake applies, it indicates a brake-pipe leak. This may occur past the emergency valve *10* or the check-valve-case gasket *14*. If the blow continues and the brake does not apply, it is probably due to a leak from the auxiliary. Open the cut-out cock, and apply the brake lightly; if the blow continues, it indicates a leaky slide valve. If the blow ceases, the slide valve is tight, and the cause of the blow should be sought elsewhere.

To test for an auxiliary-reservoir leak, leave the brake applied for a few minutes to see whether it will release or not. It probably will release; provided the leak from the auxiliary reservoir is greater than can be supplied by the leakage of air from the brake pipe into the auxiliary reservoir past the triple piston. If it releases, the source of the leak will usually

be found in the auxiliary tube or gasket *25*. The gasket may be removed and examined and the auxiliary tube tested by first removing the auxiliary reservoir. Next, plug one end of the tube *b*, stand the reservoir on end, and fill the tube with water, allowing it to stand for several minutes. If the tube leaks, it will be indicated by the water lowering in the tube.

If the blow at the triple-exhaust port is caused by a brake-pipe leak, it may be due to a defective emergency valve or to a leak from passage *a* into chamber *I* past gasket *14*. If either the auxiliary reservoir or the emergency valve leaks, it will be indicated by a humming noise within the valve after the auxiliary has become fully charged. This is caused by the rapid lifting and seating of the check-valve *15* in supplying the leakage from chamber *Y* through the emergency valve or through port *y* and the auxiliary leak. When a triple is found to be blowing at the exhaust port, first try jarring the triple lightly near the emergency valve. If this does not stop it, close the angle cocks on both sides of one of the hose connections, part the hose, and apply the brake in emergency by quickly opening the angle cock. If the blow cannot be stopped, and there is not time to make the necessary repairs, cut out that brake and bleed the auxiliary of all pressure.

27. Leaky Check-Valve Case Gasket *14*.—If the check-valve case gasket leaks, it will cause a blow at the triple-valve exhaust port when the brakes are released and the triple is in release position, and when the brakes are applied with a light application, it will make them apply harder.

28. Graduating Valve *7* Leaking.—If the graduating valve *7* leaks, it is very apt to cause the brake to release when it has been applied with a light application. This valve controls the passage of air from the auxiliary reservoir to the brake cylinder, and in case it does not entirely close the service port when the triple piston assumes lap position, auxiliary-reservoir pressure will continue to pass to the brake cylinder until brake-pipe pressure exceeds auxiliary-

reservoir pressure sufficiently to move the triple piston to release position.

If the graduating valve leaks so that brake-pipe air can feed through the quick-service ports into the brake cylinder, when the triple is in quick-service lap position, it will permit the brake-pipe pressure to equalize with the brake-cylinder pressure; also, it will tend to delay the release of the brake.

29. Quick-Service Ports Blocked Up.—If the quick-service ports *o* or *q* in the slide valve or *y* in the slide-valve seat should become blocked or obstructed, it would result in a failure of the triple thus affected to vent brake-pipe air into the brake cylinder during a service application, which, on the initial service reductions, would cause the loss of a slight amount of brake-cylinder pressure. In a long train, no material detriment to the action of the brakes will be observed if only a few of the triples in the train have their quick-service ports blocked, and no attempt should be made on the road to remedy such a defect. This defect may be detected while charging an empty auxiliary reservoir by the absence of the buzzing noise caused by brake-pipe air feeding past the check-valve *15*.

30. Stopped-Up Exhaust Port.—If the port *x*, Fig. 4, or the restricted portion of the exhaust cavity in the slide valve in the K-1 triple valve, becomes stopped up with dirt, it will prolong unduly the release of its brake, provided the triple is located near the front of the train.

31. Dirty Strainer *16*.—A dirty strainer *16* may cause the auxiliary reservoir to charge very slowly and may not allow its brake to apply on account of the reduction being made through it too slowly.

32. Check-Valve *15* Leaking.—A leaky check-valve *15* can do no harm until equalization takes place. When brake-pipe pressure is reduced below the brake-cylinder pressure, air from the brake cylinder feeds into the brake pipe until they equalize, thus reducing brake-cylinder pressure

and in some cases increasing brake-pipe pressure sufficiently to force some triples to release position and release their brakes. This is especially the case on cars on which the brake-piston travel is unusually long, permitting a low equalization between the auxiliary-reservoir and brake-cylinder pressures. In the event of a break in the brake pipe or of a burst hose, the brakes will apply quick action and all the brake-pipe air will escape to the atmosphere. Then, if the check-valve leaks, brake-cylinder air can pass to the brake pipe and the atmosphere and allow the brake to leak off.

33. Slide Valve *3* Leaking.—A leaky slide valve *3* will usually cause a blow at the triple-valve exhaust port whether the brake is applied or not, and will tend to release the brake when applied.

34. Emergency Valve *10* Leaking.—With brakes released, a leak in the emergency valve *10* will cause a constant blow at the triple-valve exhaust port, accompanied frequently by a buzzing noise in the triple valve. When the brakes are applied with a light application, such a leak will allow brake-pipe and brake-cylinder pressure to equalize, and this may cause wheels to slide, especially on a long train having a large volume of brake-pipe air with which to equalize. If the emergency piston becomes cocked, or stuck in its cylinder, it will hold the emergency valve from its seat and permit brake-pipe air to flow past the valve into the brake cylinder and then out through the triple exhaust port to the atmosphere, causing a constant blow and a large waste of air.

35. Gasket *25* Leaking.—Gasket *25* is located at the connection where the triple valve is bolted to the auxiliary reservoir. If it is leaking, auxiliary-reservoir air is apt to feed through the leak into passage *d* and then to the triple-valve exhaust port and the atmosphere, provided the triple is in release position. When the brake is applied with a light application, this leak will tend to cause it to release.

36. Auxiliary Tube *b* Leaking.—A leak in auxiliary tube *b* will cause a blow at the triple-valve exhaust port when

the triple is in release position and will tend to release the brake after it has been applied by a light application.

37. Brake-Cylinder Packing Leather Leaking.—If the packing leather leaks, it will allow the brake to leak off. If it leaks badly, the brake may not apply in service applications but usually will apply in emergency. A brake with this defect should not be cut out, but should be left cut in in order that all available braking power may be had in case of an emergency.

38. Weak or Broken Retarded-Release Spring *33*. If the retarded-release spring *33* is weak or broken, it will affect the free release of the brakes. The increase of pressure in the brake pipe when releasing the brakes will hold the triple piston and slide valve in retarded-release position too long if the spring is weak, and indefinitely if the spring is broken. This will also prevent the prompt recharge of the auxiliary reservoir. To remedy this defect, a spring of the proper tension should be applied.

CARE OF EQUIPMENT

39. Cleaning the Brake Cylinder.—To clean a brake cylinder remove the piston and thoroughly clean all parts with kerosene; special care should be taken to get the leakage groove clean. Remove the follower and expander ring and see that the packing leather is soft and in good order. The walls of the cylinder should be greased with a heavy lubricant, and a little lubricant should be put in the expander-ring groove before replacing the ring. Great care must be taken in replacing the expander ring, as it is very apt to get out of place.

40. Cleaning the Triple Valve.—To clean the triple valve, take it apart and immerse the triple piston, slide valve, and graduating valve in kerosene. Clean the emergency valve and piston and the check-valve without oil and examine these parts and see that they are in good condition. Remove

all dirt from the inside of the triple valve, and clean the triple piston and slide-valve bushings and all ports. Clean the strainer located at the connection *W* and the one in the branch-pipe tee. If the gaskets are not in good order, they should be replaced by new ones. See that the retarded-release device and the graduating stem and spring are in good order. Then remove the parts from the kerosene, thoroughly clean the triple-piston packing ring without removing it from the piston, and clean all ports, cavities, and passages in the slide and graduating valves. Lubricate the triple-piston packing ring and its bushing, the slide-valve face and seat, and the graduating-valve face and its seat, using oil especially prepared for this purpose. Too much oil will make the triple too sensitive and is apt to cause undesired quick action. After assembling all the parts, test the triple valve on the testing rack.

NOTICE

The instruction matter in this Section relating to freight trains applies to trains of any length, the locomotive of which is equipped with the E T equipment and has a large air-pump and a large main-reservoir capacity.

TRAIN CONTROL

HANDLING OF FREIGHT TRAINS

TRAINS EQUIPPED WITH H TRIPLES

MAKE-UP OF TRAINS

1. The smoothness and the freedom from injurious shocks with which a freight train may be stopped by means of the automatic air brake, either in a service or an emergency application of the brake, depends considerably on the condition of the air-brake apparatus; the manner in which the braking power is distributed throughout the train, especially with reference to mixed trains of loaded and of empty cars; the number of cars and the amount of free slack in the train; and the uniformity of the piston travel.

2. Distribution of Braking Power.—The length of modern freight trains as well as the great number of trains that are now handled over a division of road during a given period of time demand that careful attention be given to the manner in which the braking power of a train is distributed. To obtain the best results, trains should be so made up that the retarding power of the brakes will be as uniformly effective throughout the whole train as it can possibly be made, and that the retarding power of the rear brakes of the train will be slightly less if possible than that of the front brakes, so that the tendency during the progress of a stop shall be to keep the rear, to a slight degree only, pressing on the forward part, thus preventing any pulling-out tendency from the rear.

3. Effects of Free Slack.—During the time that the maximum number of cars hauled in a train did not exceed 50, it was possible to handle an all-air train with more freedom from shocks than a train made up of the same number of cars, part of which had air brakes coupled and operating and part of which had no air brakes. However, since the number of cars hauled in a single train has been increased to as high as 120, it is difficult to handle an all-air train smoothly. On account of the great length of such a train, a comparatively long interval of time elapses between the application of the forward brakes and that of the rear brakes. This causes the slack first to lurch quite heavily, and, later, when the force of the compressed draft-gear springs begins to be felt and the rear brakes take hold, to stretch out, often with sufficient force to part the train. The necessity, therefore, of having a proper make-up of train and of observing methods of brake handling that will permit the slack to adjust itself throughout the train in the easiest manner possible is very evident. The subject of slack control can best be understood by observing closely the effects of slack in the various classes of trains that are handled. In this way better provision can be made against damage and break-in-twos due to slack control.

4. Effects of Unevenly Distributed Load.—When a long freight train consists of both loaded and empty cars, its successful handling will in a great measure depend on the arrangement of these cars in the train. As a train may be started and kept in motion with greater ease if all the loads are assembled together and placed at the front of the train, it is the prevailing custom to do this, thus bringing all the empties at the rear of the loads. Although this arrangement in many ways is an advantage, yet it places the brake at a big disadvantage. There will be a much higher rate of brake retardation on the empty part of the train than on the loaded part, which will result in putting very heavy strains, sometimes quickly applied, on the drawbars and couplers, often causing them to part, and frequently resulting in considerable damage to the draft gear.

For example, in a mixed train made up of 25 loaded cars and 50 empty cars, the retarding force of the empties will be about *eight* times as great as that of the loads. This results in the empties holding the loads from the rear, and the tendency of the loads is to run away from the empties, resulting in a heavy drawbar *strain* that may result in the parting of the train. This tendency may be greatly overcome by placing not more than 10 empties next to the engine, ahead of the loads.

Dynamometer tests conducted by P. J. Langan, superintendent of air brakes for the Delaware, Lackawanna, & Western Railroad, to determine the best make-up for mixed trains so as to reduce shocks to a minimum, resulted in the adoption by that road of the following schedule for trains containing not more than 30 cars: If there are 10 or fewer than 10 empties, place all the empties behind the loads; if there are 11 to 20 empties, place half ahead of the loads and half behind them; if there are more than 20 empties, place not more than 10 empties ahead of the loads, and the rest behind them.

There should never be more than 10 empties next to the engine, because more would tend to induce buckling of the train. In case the train parts, the empties at the rear assist in preventing the rear part of the train from running in and colliding with the front part. In all cases, the car next to the engine should have a quick-action brake cut in and operative, and behind this not more than one brake should be cut out in succession. The law now requires that all air brakes in the train be cut in and operated, and the minimum number of brakes must be 85 per cent. of the number of cars in the train.

5. Effects of Unequal Piston Travel.—If a wide difference in piston travel exists on the cars that make up the train, the initial brake-pipe reduction of 10 pounds or less will make a great difference in the amount of brake power developed on the individual cars. For this reason, it is much better to adjust all piston travel (standing) at between 6 and 8 inches and to maintain it at this figure for the sake of the uniformity in braking power, the easier slack adjustment, and the more prompt and uniform release of brakes that may be effected.

CHARGING THE TRAIN

6. Before coupling an engine to the train, the brake system on the engine should be fully charged, so that time may be saved and, provided yard testing plants are employed, the necessary test of the brakes may be made without delay.

If the train has to be charged after coupling the engine to it—that is, after coupling the hose and opening all angle cocks except the rear one, which should be closed—the handle of the brake valve should be placed in release position and left there for at least 15 or 20 seconds. This will permit the main-reservoir and the brake-pipe pressure to equalize rapidly and thus hasten the work of charging. When the brake-pipe pressure increases *to nearly standard pressure*, the handle should be returned to the running position and the work of charging finished with it in this position.

INSPECTING AND TESTING THE TRAIN

7. Terminal-Yard Inspection and Test.—In air-brake and train operation it is very important that a thorough and systematic inspection and test be made at the terminal yard. The inspection of a train requires that every brake shoe, brake beam, brake-beam hanger, brake rod, lever, support, bolt, and nut comprising the foundation brake gear be carefully examined for defects. Missing cotter pins, broken rods, broken and missing brake shoes, brake shoes that are worn thin, etc., should be looked for, so that all these parts may be made good and the foundation brake gear be made reliable. It is on the foundation gear that the air-brake mechanism must act and through this gear that the power developed in the brake cylinder must be transmitted to the brake shoes and wheels in order to make the brakes effective. The air-brake mechanism should next be carefully examined for such defects as leaky hose-coupling gaskets; leaky, porous, and defective hose; angle cocks that leak and that have handles broken, bent, or missing; loose brake pipes; missing or loose pipe clamps; leaky pipe unions; loose retaining-valve pipes and pipe joints; loose sup-

porting bolts for the auxiliary reservoir and brake cylinder—in a word, every part of the apparatus should be known to be properly secured to the car body and framing and to be in serviceable condition.

Then, after coupling up all hose and opening all angle cocks except the rear one, the train should be charged in the manner just explained, after which the brakes should be applied with a 20-pound service reduction. Inspection should then follow, to locate all leaks and to determine the length of the piston travel, as well as to see whether or not each brake has applied and that none leaks off during the time occupied in inspecting.

Brake-pipe leakage is detrimental to safe and satisfactory brake operation, and for this reason it should be reduced to a minimum before the train is allowed to depart. Most brake-pipe leakage occurs at the hose couplings, through porous hose, and at the triple-valve unions. Leaks at the hose couplings and triple-valve unions may be detected by the sound, and those through porous hose can be easily detected by coating the hose with soapsuds, which should be done whenever practicable.

Leaks and improper piston travel that are found during the inspection should be marked, so as to identify them and to facilitate making the necessary repairs after the release has been made. After this inspection, the brakes should be released, and the train again inspected to see whether all brakes have properly released. If any brakes that have failed to apply or to release or that have leaked off during the time of inspection, are found, the cause should be ascertained and the proper remedy applied. Good results in air-brake operation depend greatly on intelligent terminal-yard inspection and testing and on the making of all repairs that this inspection shows to be necessary.

If the train is to be handled on grades that demand the use of the pressure retainers, this part of the equipment, together with its pipe connections, should be thoroughly examined and tested to make certain that it is in condition to render efficient service; that is, free from leakage and with both exhaust ports in the retainer open and free from dirt.

After the test, a report should be made to the engineer and conductor, showing the number of loaded and empty cars and their position in the train; the number of air cars in good order and the number cut out; the condition of the piston travel; the number of retainers, if they are to be used, that are working properly; and also the general condition of the train.

8. Terminal-Roundhouse Inspection and Test. Before the locomotive is allowed to leave the roundhouse, its brake equipment should be thoroughly inspected and tested, to make certain that it is in good operative condition. The inspection should be made after the main reservoir has been drained, the brake pipe blown out, and the pump has charged the system with pressure, and should consist in a close examination of all air pipes and pipe joints, so as to determine their physical condition and to detect any leakage.

The foundation brake gear should be carefully examined for thin, broken, or missing brake shoes; defective brake beams, brake levers, brake-beam hangers; missing bolts and cotters; etc. After having completed the external inspection and made such repairs as are found necessary, the automatic brake should be applied with a 15-pound service reduction and the action of the pump governor noted. It will be necessary to observe whether or not the governor permits the pump to accumulate maximum main-reservoir pressure, and at what pressure the pump governor throttles down the pump; also to note what cylinder pressure is obtained, as indicated by the brake-cylinder air gauge, and whether this pressure is maintained constant during the time that the brake is held applied. After the brake is fully charged, the number of pump exhausts should be noted, because they are a fair indication of the amount of the brake-cylinder leakage. The brake-piston travel should be noted to see whether or not it is too long. Next, the brake should be released by placing the automatic brake-valve handle in running position, and the time required to release, which should be about $3\frac{1}{2}$ seconds, noted. After this, the brake should be applied with the independent brake valve, leaving the handle in slow-application position and noting the

maximum brake-cylinder pressure obtained. This should be 45 pounds; any variation from this amount indicates that the reducing valve for the independent brake valve is either leaking, or is not properly adjusted, or that there is leakage into the application cylinder of the distributing valve from some other source. After this test, the brake should be released by placing the independent brake valve in release position, and the time required to exhaust the brake-cylinder pressure noted. The time should not vary materially from that given for the automatic brake, namely, about $3\frac{1}{2}$ seconds.

The adjustment and the operation of the safety valve should be tested by making a service reduction of 20 pounds, after which the handle of the automatic brake valve should be placed in emergency position. The pressure-maintaining port in the automatic brake valve will supply air to the application cylinder and increase the pressure therein up to the point at which the safety valve opens, which should be 68 pounds. During the application and release of the brakes, and the variations in brake-pipe and main-reservoir pressures that occur while making the tests, the action of the pump governors and of the feed-valve and reducing valve should be carefully noted, so as to determine the degree of sensitiveness and the accuracy with which they control the pump and regulate the pressure. If either is sluggish in its action, it should be replaced by one in good condition. A test gauge that is known to be correct should be applied to the brake pipe, and the pressure indicated by the engine air gauges carefully compared, first with the handle of the automatic brake valve in running position and then with it in release position.

After the test of the engine gauges, the accuracy of the brake-cylinder gauge may be determined with sufficient closeness by making a brake-pipe reduction and noting accurately the amount, since the gauge should indicate about $2\frac{1}{2}$ pounds of cylinder pressure for each pound of brake-pipe reduction.

The driver brake-piston travel should not exceed 4 inches, and that of the tender and engine truck brake, 6 inches. The pump should be observed during the time that it is working to see whether it operates smoothly; that is, without any unusual

clicks or pounds. The air valves also should be tested by holding the hand near the air inlet to see whether the suction is strong and regular, without any back puff of air, on both the up and the down strokes.

9. Running Test.—The running test, which consists in making a light service application and noting the brake-pipe exhaust made while the train is in motion, is resorted to as a final check on the terminal testing. It should be made soon after departure from the terminal station, as an assurance against possible failure or oversight of the inspectors or crew to perform their full duty. It should also be made when approaching meeting points, railroad crossings at grade, junction points, drawbridges, and terminal stations, before commencing the descent of a heavy grade, and, in fact, at such places as will not permit of running by the designated spot without likelihood of disaster resulting. The running-test application should be made, without closing the throttle, at a point far enough back from the stopping or slow-down place to permit the crew to stop the train with the hand-brakes should the air brake fail to operate as expected. This test should also be made after a train has been parted and recoupled, or after it has stood for a long time in a place where there is opportunity for tampering with the hose or angle cocks. The running test is an important one, and just how and when it ought to be made should be thoroughly understood by an engineman before he is permitted to handle the brakes on the road.

When moving long, heavy freight trains out of yards or terminals the track of which is level or the grade is up, it is not always practical to make the running test; but when the grade is down, it can be made, in which case, of course, the brakes must soon be applied in the usual manner to control the train. With a freight train, the terminal standing test is very important; it should always be properly made, and on no account omitted.

HANDLING THE TRAIN

10. Running Precautions.—While running the train, the engineer should always know whether or not the pump is working properly and maintaining the desired pressure. He should watch the air gauge carefully to make certain that the correct pressures are being kept up. When double-heading, the second engineman should watch the brake-pipe air gauge of his locomotive to see that the engineer of the head engine is maintaining the pressure properly, as well as making the proper reductions to apply the brakes satisfactorily.

11. Service Stops.—When making a service stop with a modern freight train, the slack in it must always be considered. Formerly, when part-air trains were the rule rather than the exception, it was necessary after shutting off steam to allow sufficient time to elapse to permit the slack to adjust itself. However, with all-air trains, as is now generally the rule, the train, especially if it is long and if empty cars are at the rear, will stretch during the progress of the stop. For this reason, it is better to commence the brake application just before shutting off steam—while the train is stretched—and to make the initial service reduction no heavier than is required to apply the brakes lightly throughout the whole train.

With a very long train, a service reduction not exceeding 10 pounds will be sufficient to do this and at the same time reduce the speed very materially. If it is determined that a 10-pound reduction will stop the train, the brake-valve handle should be placed in service position and left there until the train stops, the idea being to keep the brake-valve exhaust blowing so that the brakes will be applying harder on the front end of the train than on the rear while the train is coming to a stop. For a train shorter than the preceding and running at a higher speed, the initial reduction may be between 6 and 8 pounds; and, after the slack has stretched out, a second reduction sufficiently heavy to stop the train may be made. In trains of 35 cars or fewer, the slack is not of so much importance. After the first reduction has taken full effect, the following

reduction may be as heavy as speed and other circumstances require to make the desired stop. Before attempting to start a train that has been stopped, ample time should always be allowed for all brakes to release.

12. Quick Action During Service Application.—In making a service application, the brakes are liable to set quick action. This may be due to: (1) improper brake manipulation, (2) excessive brake-pipe leakage, or (3) a defective triple.

1. *Improper Brake Manipulation.*—The delay caused by moving the brake-valve handle from running to lap position and allowing it to remain in this position for 6 to 8 seconds before commencing the service reduction, often permits brake-pipe leakage to move one or more of the triples at the head end of the train to the position where the collar, or lug, on the piston stem engages the slide valve very gently. Thus, when the service reduction is begun at the brake valve, a somewhat greater differential between the auxiliary pressure and brake-pipe pressure must be made to move the triple piston and slide valve, with the result that this differential is sometimes great enough to cause some one of the triples to move to the emergency position and cause undesired quick action.

Failure to practice the kick-off movement after releasing brakes on long trains is often responsible for the occurrence of undesired quick action when the next service application is begun. The reason for this is that, as explained for the delay in lap position, the overcharged reservoirs cause their triple pistons to move back to a position where the piston lugs engage with the slide valve, in which position they will remain until a service reduction is begun.

2. *Excessive Brake-Pipe Leakage.*—Excessive brake-pipe leakage, which, as stated, is conducive to undesired quick action, is usually to be found at hose couplings and the triple-valve-union connections of the cross-over pipe. After a parting or a break-in-two occurs while the train is in motion, brake-pipe leakage will generally be found to have increased considerably at the points named. This leakage, in addition to the brake-pipe reduction at the brake valve, often causes

undesired quick action on account of the piston moving until the shoulder on the stem strikes the slide valve, as just explained, or on account of the leaks making the brake-pipe reduction quicker than ordinarily.

3. *Defective Triples.*—The defects in the triple that cause undesired quick action are improper lubrication, too much tension of the slide-valve spring, a weak or broken graduating spring on very short trains, a broken graduating pin, or a tight-fitting triple piston packing ring.

To locate the troublesome valve in long trains, it will be necessary first to place observers along the train and as far away from the side as practicable, so that when the brakes apply they can tell whether the undesired quick action starts from the front or from the rear. If it starts from the front, the rear portion of the train may be cut off, by closing an angle cock, while testing for the defective triple. After having ascertained the vicinity in which the triple that is causing trouble is located, it can be detected by making a service reduction of 5 pounds and noting which brake pistons do not move out. When these are found, the observers should be instructed to watch them closely while another reduction of 3 pounds is being made to bring the defective triple into action. The triple that is found to be at fault should be cut out, and then, with the whole train cut in, the system should be recharged and a 10-pound reduction made so as to be positive that the right triple has been found and that the brakes will apply in service without undesirable quick action.

Proper cleaning and lubricating and the use of proper lubricants, which are now known and may be easily procured, will eliminate all undesired quick action that may be charged to improper lubrication.

13. Slow-Downs.—If it is necessary to reduce the speed of a long freight train, an application of the locomotive brakes with the independent brake will often be sufficient, because the speed of such a train is seldom very high. Good judgment, however, must be exercised in applying the independent brake. If it is not used very cautiously, terrific shocks in the train will

result; and if it is held applied too long, it will overheat the tires.

If the automatic brake has to be used to slow down the train, it is often better to come to a full stop before releasing than to attempt to release while under motion because of the danger of breaking in two. However, in a train consisting of 50 cars or fewer, the release should be made by placing the automatic brake-valve handle in release position for about 15 seconds and then returning it to holding position, taking care in the meantime to maintain sufficient brake-cylinder pressure with the independent brake valve to keep the slack together and to prevent a break-in-two.

14. Water-Tank and Coal-Chute Stops.—In making water-tank or coal-chute stops, the engineer should not attempt to spot the engine at the water spout or coal chute. The better plan is to stop short and cut off the engine to take coal and water, afterwards coupling up to the train and charging up and testing the brakes in the usual manner before proceeding.

15. Emergency Stops.—At times, emergency applications are necessary to avert accident and prevent the loss of life and property. There is but one thing to do in cases of actual emergency: Quickly place the handle of the automatic brake valve in emergency position and leave it there until the train stops or the danger is passed.

16. Trains on Grades.—Grade work is a very important branch of railway operation, because of the fact that it does not permit of any chance to be taken with the equipment, either with respect to its condition or with the method of its manipulation.

In order to realize the necessity for exercising great care in handling trains on grades, a clear understanding of the terms *force of gravity* and *per cent. of grade* is essential. By **gravity** is meant that force which the earth exerts on a body at all times, giving it weight and causing it, when unsupported, to fall. Gravity is constant in action, and whenever a body is to be lowered from one height to another, the force that gravity exerts must be neutralized by another force acting in opposi-

tion to it to the extent required to permit the body to reach the lower level without damage or injury. A train about to commence the descent of a grade is a body that is to be lowered from one height to another against the force of gravity, and the brake is the medium through which the necessary neutralizing force is applied that permits the train to be lowered at the required degree of rapidity to prevent damage, and to avoid the danger of a runaway.

The **per cent. of grade** should be clearly understood from the following: Assume that in 1 mile of railway the vertical rise is 52.8 feet. This 52.8 feet divided by 5,280, the number of feet in a mile, will give $\frac{1}{100}$, which is equal to 1 per cent.; that is, the vertical rise is $\frac{1}{100}$, or 1 per cent. of the length of the grade, and the grade would be called a *1-per-cent. grade.* If the vertical rise in 1 mile were 105.6 feet, or twice 52.8 feet, the grade would be called a *2-per-cent grade;* if three times 52.8 feet, or 158.4 feet, it would be a *3-per-cent. grade;* and so on.

As was said before, gravity is a force that acts continuously and it is just equal to the weight of a body. Hence, on a body free to fall vertically downwards, gravity exerts a force equal to 100 per cent., or the full weight of the body, in accelerating its motion. On the other hand, if in dropping vertically downwards a distance of 52.8 feet the body must move along an inclined plane a distance of 5,280 feet, then only $\frac{1}{100}$, or 1 per cent., of the force of gravity will be exerted toward accelerating the motion of the body. In other words, $\frac{1}{100}$ of the weight of the body is the constant accelerating force that produces motion along the inclined plane, and when the grade becomes level, gravity of course does not exert any force on the body to produce motion along the level. In ascending a grade, a locomotive not only moves the train along an inclined plane, but also lifts the whole train through a distance equal to the vertical height of the grade.

17. From what has just been said, it will be seen that on down grades there is absolute necessity for having at each instant not only sufficient braking force to offset the force of gravity but an additional braking force for stopping the train.

Therefore, before commencing the descent of a grade it is important to be sure that the auxiliaries are fully charged and that the brakes are in such operative condition that they will respond when wanted with the requisite holding power. This can best be determined by testing the brakes according to the prescribed rules in force on the road, then recharging the brake system to the pressure prescribed as standard for that grade, and, finally, turning up the number of retainers that experience has indicated are necessary for the grade. Another thing, of great importance is, never to let the speed of the train increase over that prescribed by the rules.

18. After a train on a down grade has attained sufficient speed to withstand a service application without stalling, a reduction of not less than 12 pounds should be made. With this reduction the train should, provided the brakes were held applied, come to a stop. If it will not bring the train to a stop, a reduction sufficiently heavy to stop it should be made, and the brakes should then be inspected to ascertain the cause of failure to hold as they should. If it is seen that the 12-pound reduction will control the train, the recharge of the auxiliaries may be commenced by placing the brake-valve handle in release position for 20 or 30 seconds and then in running position until it is desired to increase the brake-cylinder pressure, when a reduction of from 6 to 8 pounds will usually suffice to reduce the speed to the rate it is desired to maintain.

In grade work, good judgment should be used in handling the brakes, so as to maintain as uniform a rate of speed as possible. In the exercise of this judgment, advantage should be taken of the curves and the let-ups in the grade for recharging the reservoirs. However, just how this should be done is something that cannot be explained here, because no two grades nor no two trains are just alike; it must be acquired by experience.

As modern engines are heavy, overheating of tires is very likely to result if the driver brakes are not used with discretion. This is especially the case with the E T locomotive equipment if the grade is very steep and long. Nevertheless, there need be no difficulty in regulating the amount of brake

work the driver brakes should do, because they may be released at any and all times with the independent brake valve without disturbing the automatic brakes on the train. Locomotives that operate on long and heavy grades are usually provided with special driver-brake cut-out cocks. These are located in the cab and are to be used by the engineer for the purpose of preventing tire heating.

19. As some very long all-air trains have to be handled on grades, there is a demand for the skilful use of the straight air or an independent brake on the engine. For example, if the speed of the head part of a train that is being pulled on to a grade commences to increase over the speed of the rear part so rapidly that there is a possibility of breaking the train in two, the independent brake should be used to keep the slack from running out too hard and until the rear comes over the summit. Again, when on the grade, and the automatic brake-valve handle is placed in release position, the independent brake should be applied to prevent the slack from running out rapidly, and to assist the retainers in its gradual adjustment.

20. In all grade work, it should be the aim to make certain that the brakes are sufficiently powerful to prevent the train from getting away and to put them into operation before the speed of the train exceeds the maximum allowable. Many runaways have occurred simply because the speed of the train was allowed to get too high before the brakes were applied on the initial application, or because, through carelessness or ignorance, or both, the air was frittered away by frequent small and ineffective reductions. It should be remembered that the holding power of a brake shoe reduces as the speed increases.

If sufficient pressure retainers are used and the brake cylinders are once charged with pressure, the aim should be to control the speed by frequent comparatively light reductions and recharges. This method will maintain a more uniform rate of speed while descending the grade, and at the same time give a higher average brake-pipe and auxiliary-reservoir pressure, which will always be available in case an emergency arises and a quick stop is imperative. Close watch should be kept

of the air gauge in descending grades, so as to know that the pump is maintaining the required pressure.

21. In starting a train that has been stopped on a grade, care should be taken to see that all wheels commence to rotate. As the pressure retainers hold pressure in the brake cylinders, there is always danger that some of the wheels may not start to rotate, in which case they would be skidded along a sufficient distance to flatten and ruin them.

It is customary on most roads to increase the brake-pipe and main-reservoir pressure before starting down long, heavy grades. Also, the speed of the air pump is increased to meet conditions. When frequent applications are made on a descending grade, the brakes should be released by moving the automatic brake valve handle to release position for 30 to 40 seconds, then to running position for 8 seconds, then back to release for 2 seconds, to kick off any brakes that may have reapplied, and then back to running position. If a stop is made, steam should not be used for 1 full minute, so as to allow the rear brakes to release and blow down to zero. The driver brake should be released by the independent brake valve after each application except the first and the last, to prevent overheating the tires. On starting the train, the independent brake should be applied at once to prevent the head end from running out too quickly and snapping the train in two. After the engine has moved five or six car lengths, the engine brake should be graduated off.

After the first release note should be taken of the efficiency of the pressure-retaining valves; that is, the manner in which they are holding. They should always be able to hold the speed of the train in check during the time required to recharge the auxiliaries completely.

A steam pressure of at least 175 pounds must be maintained while on a grade so as to insure sufficient steam pressure for the air pumps to maintain main-reservoir pressure. If for any reason the brake-pipe pressure cannot be maintained, the train must be stopped at once and the assistance of the train crew obtained for controlling the train. If a reduction of

more than 12 pounds is required to control the speed when the retainers are up, the engineer should receive the assistance of the train crew. Also, when ascending a grade, the trainmen must always be prepared in the event of a break-in-two to prevent the detached part from running down grade by promptly applying the hand-brakes.

22. If a train is to be held standing on a grade for any length of time, the automatic brake should never be depended on to hold it. Instead, just as the train comes to a stop, the independent brake should be applied in full and the engine reversed. The handle of the automatic brake valve should then be placed in release position for a few seconds and then in running position. If the independent brake is not sufficient to hold the train standing, enough hand-brakes to supply the deficiency should be applied. In this way, the auxiliaries may be kept fully charged and full brake power will be available at any instant it is required.

A train with the engine detached should never be left standing on a grade unless sufficient hand-brakes are applied to hold it. The air brake may leak off and disastrous consequences result, as has been the case in several instances in the past when the air brake alone has been depended on to hold the train.

If a train becomes parted on a grade, whether accidentally or in some other way, the angle cocks on each car at the point of separation must be closed and the part of the train not coupled to the engine secured by hand-brakes on all cars, beginning at the car on the lowest part of the grade.

23. The number of retainers to use on a grade depends on local conditions as to grade, the make-up of the train, the condition of brakes, etc. Each road usually prescribes the number to be used under given conditions, and these instructions should always be lived up to. Where no instructions are given, the following may be used as a guide as to the number of retainers to use on a grade of $1\frac{1}{4}$ per cent. or more: With a train of all loads, all retainers should be used; with a train of all empties, the retainer handles at the head end on one-third of the cars should be turned up; on mixed trains of 50 or

more cars, the retainer handles on all the loads and on one-third of the empties should be turned up; and on trains of more than 55 cars the retainer handles on all except the 6 rear cars should be turned up. Retainer handles should not be turned down until the train is at the bottom of the hill. In the event of a car journal heating while on the grade, the brake of that car should be cut out until the foot of the hill is reached, when it should again be cut in.

24. Double-Heading.—In double-heading, the engine having the larger air-pump capacity should be placed ahead and have control of the brakes. The double-heading cock on the following engine, whether coupled next to the leading engine or placed elsewhere in the train, should be closed and both brake-valve handles carried in running position. The cylinder pressure on the following engine may be regulated as desired by means of the independent brake valve, either in the way of reducing or increasing it, without interfering with any of the other brakes on the train. The enginemen should watch the brake-cylinder gauges so as to govern the cylinder pressure in such a manner as to prevent overheating of tires and prevent shocks in the train, which produce tendencies to break it in two. The engineer of the second engine should also watch the brake-pipe air gauge so as to know that the proper brake-pipe pressure is being carried at all times and that the operating engineman is making the proper reductions when applying the brake.

If, for any reason, the air on the head engine fails, the engineer on that engine should signal the second engineer by the proper whistle signal of the road, and when answered he should cut out the air on the lead engine so that the second engineer can control the train until his engine changes positions with the lead engine. On cutting in, the engineer of the second engine should try the brakes at once to determine whether or not he can control the train. If he does not do this, the engineer of the head engine should immediately cut in and apply the brake, stop the train, and have a definite understanding before proceeding.

In making a service stop with two engines coupled together and placed at the head of the train, the aim should be to have the brake-pipe pressure reducing at the operating brake-valve as the train comes to a stop, and thus avoid a possible break-in-two.

25. If more than one engine having the E T equipment is used on the same train, the rule governing the older equipment should be observed, no matter in what part of the train the engines may be. In other words, the double-heading cock, or the brake-valve cut-out cock, on all engines except the one from which the brakes are to be operated should be closed and the handle of the brake valve carried in running position. The brake valve on the engine from which the brakes are operated, will operate the brakes on the engine or engines in the train that have their double-heading cocks closed.

In double-heading, the independent brake valve on the engines fitted with the E T equipment may always be used to control the brakes on that engine without interfering with the operation of the automatic brakes on the rest of the train or even on the same engine. After a release of the automatic brake is made by the operating engineer there is danger of overcharging the pressure chamber of the distributing valve of the locomotive having its double-heading cock closed; this is apt to cause the brakes to creep on. To avoid this annoyance the operating engineman should be signaled to release brakes, which he should do by moving the automatic brake-valve handle to release position and immediately back to running position.

26. Stuck Brakes.—By so-called *stuck brakes* are meant brakes that do not release along with the others or brakes that remain applied for some time after the others have released. They are often caused by some defect in the foundation brake gear, such as the fouling of a lever or the wedging of a bolt between the brake beam and the spring bolster; also, a retainer with the handle turned up, a plugged exhaust port, and, sometimes, a leaky emergency valve in the triple may be the cause of the trouble. All these defects should be discovered during

the terminal test of the brakes and corrected before the train is allowed to leave the yard.

Causes of stuck brakes attributable to wrong manipulation are those resulting from reapplication of the brakes on the head part of the train, due to overcharging during release, and those resulting from delayed release, especially toward the rear, due to reducing the brake-pipe pressure below that at which the auxiliary and brake cylinder equalize during the service application. To avoid this trouble, the handle of the brake valve, when releasing the brakes, should not be held in release longer than from 10 to 15 seconds with any length of train, and in 4 or 5 seconds after returning it to running position it should be moved to release and back to running once or twice. These manipulations will kick off any of the head brakes that may have reapplied without appreciably increasing permanently the brake-pipe pressure. When making a service application, a reduction of more than 15 pounds should not be exceeded, if possible. Then, when release is attempted, all triple pistons will be balanced between auxiliary and brake-pipe pressure, and the increase of brake-pipe pressure will move them promptly to release position.

27. Wheel Sliding.—Probably more wheels are flattened by starting a train and pulling it a long distance before the brakes release than in any other way. The engineer should therefore endeavor to manipulate the brake valve in such a way as to effect a prompt release of all brakes in the first instance, and to determine whether or not all wheels are turning the train crew should watch the train as it pulls past them. It is especially necessary to watch the wheels on long trains, because variation in piston travel will sometimes hold a brake applied long enough before releasing to slide the wheel until it is flattened. The resistance of one or two applied brakes does not affect the large, powerful locomotives sufficiently to call the attention of the engine crew to the fact that they are sliding, and flat wheels are likely to result unless prompt measures are taken to bleed auxiliary pressure below that in the brake pipe, or to knock the shoes loose.

Wheel sliding that is chargeable to the air-brake apparatus may be said to be due largely to the causes mentioned for stuck brakes. If carried far enough, sliding will cause injurious flat spots. Therefore, when flat wheels are found, their condition may usually be traced to sliding a short distance when under loaded cars, and to sliding a long distance when under empty cars. In the consideration of the flat-wheel problem, the length of the train, the location of the car in the train, the load carried by the car having the flat wheel, the amount of sand used, as well as the time of applying it while making stop and when starting, and the distance the sliding wheel is pulled along the track, must all be considered.

Much wheel sliding could be prevented by making a thorough and systematic inspection at terminals and then adjusting the piston travel intelligently and repairing all defects in the foundation brake gear before the train leaves the terminal, as already explained. After the train leaves the terminal, the precautions necessary in manipulating the brakes to prevent them from sticking will at the same time prevent the wheels from sliding, and in the majority of cases flat wheels.

Cars that are being handled in yards with the hand-brakes applied have their wheels flattened because they are slid over long distances. In cold weather, the brake shoes may often be frozen to the wheels so hard as to prevent them from rotating when moved. If a train fitted with pressure retainers stops and is then started, there is danger of some wheels sliding and of being dragged far enough to flatten them. The same thing is true where hand-brakes are applied to hold the train while standing on grades and the train is then started without releasing the hand-brakes.

28. Break-In-Twos.—When a service application is started, the brakes on the front of a train commence to act immediately, causing the slack to close in tight and compress all drawbar springs, and later, usually at the time that the speed of the rear is considerably reduced, the rear brakes commence to take hold. The energy in the compressed drawbar springs then asserts itself, and this, added to the retarding effect of

the rear brakes, brings on a heavy stretching strain in the train that not infrequently is greater than the drawbars can stand, and as a result the train parts, sometimes breaking into three or more pieces. To avoid this undesirable occurrence, the independent brake valve should be held in release. This will prevent the locomotive brakes from going on, and thus help to diminish the drawbar compression during the early part of the application. When the brake-pipe pressure has reduced about 8 pounds from the first reduction, the independent brake-valve handle should be returned to running position and a further service reduction made—one that will cause brake-pipe air to be flowing from the service exhaust at the time the train stops. In this method, a heavier braking power is maintained on the front of the train during the course of the stop than can be maintained at the rear. Hence, the rear cannot pull away hard from the front part of the train and break it in two.

On trains of 90 cars or more, the difference in time between the beginning of action of the front brakes and that of the rear brakes in service applications permits the closing in of the rear and the front ends, which, later, when speed reduces considerably, commence to separate rapidly and thus break the train in two just before coming to a stop. On many roads the service application is made in the manner just recommended, and, in addition, the slack of the train is prevented from closing up during the progress of a service stop and, later, in running out again with consequent danger of breaking in two, by using a light throttle while the first service reduction is being made.

If it is necessary to back up a train and stop it by means of the brakes, when the first reduction is made the brakes near the engine apply first and hardest, so that there is a tendency for the slack on the front part of the train to run out hard and break the train in two.

When applying the brake in backing up, therefore, the locomotive brake should be released by means of the independent brake valve and a light throttle should be used until the train stops.

In the starting of a long train, care must be exercised in taking the slack so as not to break the train in two. Slack

should be taken out gently, and when the locomotive has moved forwards about its own length, the throttle may be opened sufficiently to put the train in motion.

29. No attempt should be made to release the brakes on a train of more than 45 cars if the speed is 10 miles or less per hour, or if retainers are not in use. In such cases there is great danger of breaking the train in two, because the rear brakes cannot release in time to prevent the slack from running out. With trains of fewer than 60 all loaded cars running at speeds greater than 12 miles per hour, the brakes may be released without breaking the train in two if the locomotive brake is kept fully applied until the rear brakes have released. On trains of fewer than 45 cars, the release may be effected at slow speeds without danger of parting by the skilful use of the holding feature of the H-6 brake valve, or by the use of the independent brake valve; that is, by holding the locomotive brakes applied until all the train brakes have released.

In any case of release of brakes while the train is in motion, steam should not be used until sufficient time has elapsed for all brakes to release and for the slack to adjust itself.

30. Bleeding Off a Brake.—Whenever it is necessary to bleed a brake off the auxiliary-reservoir release valve should be used for the purpose, and just enough air should be drawn through the release valve from the auxiliary to permit the triple to return to release position. If the release valve is held open after the triple returns to release, it may cause the other brakes in the train to apply.

In the case of long freight trains, it may occasionally be found that a car near the rear of the train contains a brake that has not released along with the others. Before opening the release valve it is necessary to determine whether or not the pressure-retainer handle is in the proper position to permit the brake to release. If the handle is not in the proper position, it should be turned down at once; if it is already down, the release valve rod should be pulled quickly once or twice, but it must not be held open an instant after the brake commences to release. If the release valve is held open until the piston is

clear back in the cylinder, other brakes will likely commence to apply. Indeed, this will almost invariably result if the cars are cut off from the engine. In releasing any brake with the release valve, it should be closed the instant that the air commences to exhaust from the cylinder. Holding the release valve open longer than this will deplete the auxiliary, which will commence to take air from the brake pipe to supply the deficiency, and this is likely to create sufficient reduction in the brake-pipe pressure to cause other brakes to apply. In case a number of brakes located together at the rear of a long train fail to release, a partly closed angle cock should be looked for.

31. Burst Hose.—If a hose ruptures or bursts, if the conductor pulls the conductor's valve, or if the train parts, the handle of the automatic brake valve should be placed in lap position. If a burst hose is the cause of the trouble, the crew should immediately institute a search for the defective hose. As soon as the train comes to a stop, the brake-valve handle should be moved far enough into running position to feed air into the brake pipe and thus cause a blow from the ruptured hose so as to attract their attention. It is important to remember and to practice this method, in such cases, as it will help materially to save time in finding the defective hose.

In the event of a hose bursting, the engineer should immediately lap the brake valve, and as soon as the train stops, send out flags. The hose should be replaced by a new one or by the extra hose on the last car of the train, and the brakes then tested to see whether they operate properly. If unsafe to replace the hose and test the brakes at this time, the angle cock immediately in front of the burst hose should be closed; the brakes back of it should then be bled off, and the train moved to a safe place, where the hose can be replaced and the brakes tested.

32. Setting Out a Car.—When a car is to be set out or left on a side track, the brakes should be released, the angle cocks on each side of the hose that are to be parted should be closed, and the hose parted by hand. When the car is set out,

the release valve on the auxiliary reservoir should be held open until the auxiliary is depleted, and the hand-brake applied with sufficient force to prevent the car from moving of its own accord.

If the car is to be left standing on a heavy grade, the brakes should be examined before setting it out, so as to be sure that they are in perfect working order. When the car is set out, the air brake should be released and the auxiliary reservoir drained; also, before leaving it, the hand-brakes should be set securely so as to hold the car. If there is any doubt about the hand-brake holding, the wheels should be blocked or some other suitable precautions taken. In all cases, the air brake should be released before the hand-brake is applied.

When recoupling the train after setting out the car, it is necessary to make certain that all angle cocks, with the exception of the rear one, are wide open and that the system is properly charged, after which the required test of the brake should be made before proceeding.

TRAINS EQUIPPED WITH K TRIPLES

REMARKS

33. To handle satisfactorily a long train made up partly of K triples, the general location of the K triple valves throughout the train must be known. If the K triples are evenly scattered throughout the train, then, regardless of the length of the train, all service applications should be made with an initial reduction of not more than 7 pounds. This will cause all brakes to apply with a light cylinder pressure; that is, with a pressure just sufficient to adjust the slack gently. After it is felt that the slack has adjusted itself, such additional reductions should be made as the conditions of the case require to bring the train to a stop at the desired place. The brake should then be held applied until the train stops.

After a train has been stopped the brake should be released in the usual way; that is, by moving the automatic brake-valve

handle, regardless of type of brake valve, to release position for a period of 15 seconds, then to running position, and after 2 or 3 seconds to release position for a moment and quickly back to running position. This latter operation, called the *kick-off*, will release any of the head brakes that may have reapplied due to overcharging without permanently causing an appreciable increase in brake-pipe pressure.

34. If all the K triple valves are placed together at the front end of the train and are over 10 in number, then the initial brake-pipe reduction should be not over 7 pounds. After this reduction has taken place and it is learned that more is needed to bring the train to a stop, an effort should be made to have the brake-pipe air flowing from the brake valve as the train comes to a stop. This will prevent the head end of the train from surging ahead during the progress of the stop and breaking the train in two. The brakes may be safely released at slow speed if desired, because, if the number of K valves is at least ten and all are at the front of the train, its retarded-release feature, as well as the holding feature of the H-6 automatic brake, will prevent the slack from running out and parting the train. If the engine is not equipped with the E T brake, then the straight-air brake may be used to retain the locomotive-brake pressure for at least 15 seconds while the rear brakes are starting to release.

If the train is composed entirely of K valves, the initial reduction for a service stop should be about 7 pounds. This amount will usually be found sufficient to stop the train. However, if the train is short, say one containing 35 cars or fewer, and the speed is comparatively high, an additional service reduction as heavy as the circumstances require—that is, to within the limits of the equalizing point, or 18 pounds—may be made. The release may be made in the usual manner when desired, either before or after the train has come to a stop.

If all the K valves in a train are located together at the rear and are over ten in number, then the initial reduction should not be over 7 pounds. When this reduction is about to cease at the brake valve, it should be followed by another reduction

of 6 or 8 pounds; that is, one sufficiently heavy to cause brake-pipe air to flow from the brake valve at the instant the train stops. No release should be attempted until after the stop is made. In such cases, too, if the train is long, say one consisting of 50 cars or more, it is considered good practice to make the first service reduction before or without shutting off steam.

CHARGING THE TRAIN

35. The method of charging a train consisting wholly or partly of K triples does not differ materially from that already recommended. It will be well, however, to observe, that some of the earlier types of K valves that take air through the non-return check-valve to supply the uniform recharge port make a buzzing noise while charging the auxiliary. This noise should not be mistaken for a similar noise made by a leaky emergency valve. When an emergency valve leaks, there is a blow at the exhaust port of the retainer at the same time that the buzzing noise is heard; but if the buzzing continues for a part of the time that the auxiliary is charging and then ceases, without any blow taking place at the retainer exhaust, it is caused by the air that is passing through the non-return check-valve to supply the uniform recharge part.

HANDLING THE TRAIN

36. Slow-Downs.—If a train is entirely equipped with K triples, slow-downs may be made with the automatic brake and the release accomplished without any danger of parting the train. The same thing holds true if ten or more K valves on a partly equipped train are all placed together at the front end. With the K triples scattered throughout the train, however, it will be better, provided the train is long, to observe the precautions in regard to releasing recommended for the type H triple valve type. In other words, if the speed is less than 10 miles an hour, no release should be made before coming to a stop.

37. Emergency Stops.—In emergency applications, the K triple operates in the same manner as the H triple. Therefore, the instructions regarding the application of the H triple in emergency apply to the K type. In all cases of emergency, place the handle of the automatic brake valve quickly in emergency position and leave it there until the train stops. When releasing after an emergency, leave the handle of the brake valve in release position until the brake-pipe pressure has reached at least 60 pounds.

38. Trains on Grades.—A decided advantage is had in handling trains on long, heavy grades when all the cars in the train are equipped with the K type of triple, because the quick-service feature accelerates the service reduction throughout the whole length of the brake pipe, and the brake-pipe air vented at each triple goes into the brake cylinder to augment the pressure in this cylinder. Thus, time and economy in the use of air, two very important considerations in grade work, are conserved in the highest degree by the K-triple mechanism.

When handling trains equipped partly or entirely with K valves on heavy grades, the engineer should be governed by the rules and precautions given for trains equipped with the older type of valves. The manner in which the pressure retainers should be used in grade work is also governed by the rules prescribed for any other type of triple.

39. Stuck Brakes.—Stuck brakes occur most frequently in winter weather. They are more often due to the cold and frozen condition of the shoes than to any defect in the triple valve. However, as the causes of stuck brakes are precisely the same with the K triple as with the older type, the precautions to prevent them are the same. As a general rule, so far as the engineman is concerned, he must so manipulate the brake valve when releasing the brakes as to prevent unduly overcharging the brake pipe at the front end. In addition, he must practice the kick-off method to prevent the reapplication of the head brakes, and, after the brakes are all properly released and while the brakes are not wanted, keep the handle in running position. Foundation brake gears designed so that

they will permit the levers to foul are occasionally responsible for what is termed a stuck brake. Proper inspection, resulting in all necessary repairs, replacement of missing bolts, cotters, etc., will prevent in a large measure stuck brakes chargeable to foundation brake gear. Stuck brakes caused by triples with leaky packing rings or by triples in bad condition with respect to cleanliness and lubrication are usually found at the rear of the train. Such brakes should be watched, to prevent them from doing damage to the wheels, and reported for attention when the terminal is reached

40. Break-in-Twos.—With K triples, a break-in-two produces no different results from what would be had with the older type of triple. The previous instructions governing this occurrence apply in the case of trains equipped with the K triple.

41. Wheel Sliding.—Wheel sliding on trains equipped with the K triple is caused in the same manner as wheel sliding on trains equipped with the older type of triples; also, the precautions necessary for its prevention are the same as those already recommended to be observed with the older types of triples. Care should always be taken to see that all brakes are released before starting the train.

42. Undesired Quick Action.—With the K triple, the likelihood of undesired quick action is very remote, even when from neglect the condition is bad with respect to cleaning and lubrication. However, when undesired quick action does occur, the method employed for finding the disorderly valve with the ordinary type of triple should be followed.

43. Switching With Three or Four K Triples Next to Engine.—When engaged in the work of switching and handling cars equipped with K triples, some difficulty will be experienced, because the retarded-release feature will operate and prolong the brake-cylinder exhaust. Annoyance from this delay of the exhaust, however, will be greatly lessened if the running position of the brake valve is used when releasing the brakes. In this way the main-reservoir excess pressure will be

prevented from entering the brake pipe and moving the triples to retarded-release position rapidly. Returning the handle to lap position for a moment, say 2 seconds, and then back to running will effect a quick release of the forward brakes.

44. Bleeding Off a Brake.—When the release valve is used to release a brake that has a K triple, care should be taken not to reduce the auxiliary pressure more than is necessary to move the triple piston to normal release position. If a heavy reduction of auxiliary pressure is made through the release valve, the triple will move to retarded-release position and thus cause a slow release of the brake.

HANDLING OF PASSENGER TRAINS

TRAINS WITH P M EQUIPMENT

REMARKS

45. The passenger engineer will be greatly assisted in handling passenger trains smoothly and in making accurate stops by the E T locomotive brake equipment, because with it smooth brake work can be done with greater ease than is possible with the older type of locomotive equipment. The E T equipment usually has a large main-reservoir and pump capacity, and the B-6 feed-valve not only has large capacity but operates more sensitively than the older types, making it unnecessary when releasing to remain in release position longer than 4 or 5 seconds with a passenger train of 20 cars or fewer. In addition, the locomotive brake itself controls the locomotive in a reliable and satisfactory manner, regardless of its size and weight. The locomotive brakes may be released and reapplied without disturbing the brakes on the train. This brake therefore provides a margin of flexibility in handling trains that is very helpful in doing good braking and in preventing damage to driving wheels by sliding.

With the exception of the time that the handle must be held in release position and of the skilful use of the locomotive-brake holding feature, the method to be employed in handling a passenger train with the E T brake does not differ materially from that now used to handle a passenger train with the G-6 brake valve.

CHARGING THE TRAIN

46. A train equipped with the P M equipment should be charged in practically the same manner as one equipped with the G-6 valve. If long trains are to be charged up from zero, however, the handle of the automatic E T brake valve should be left in release position until the brake-pipe pressure reaches 80 or 90 pounds. If it is left in running position, all the angle cocks will be open and brake-pipe air will immediately flow into the long brake pipe and cause the pressure in the engine brake pipe to drop very low in a short time. This action will remove the feed-valve pressure from the top of the diaphragm in the excess-pressure head of the S F pump governor and cause it to operate so as to stop the pump; also, as main-reservoir pressure remains considerably more than 20 pounds higher than brake-pipe pressure for some time, the pump cannot start again until the brake-pipe pressure, combined with the excess spring pressure, is sufficient to force the diaphragm downwards and seat the pin valve. Then, of course, the governor will permit the pump to go to work and to continue without interruption until the system is fully charged. As modern locomotives usually have large main reservoirs and large pumps, the capacity of the feed-valve is not sufficient to permit the air to flow through it into a long, empty brake pipe as fast as the air can be supplied. Hence, if the handle is allowed to remain in running position while charging such a brake pipe, the main-reservoir pressure will remain more than 20 pounds higher than brake-pipe pressure for some time, and during this time the pump will remain stopped.

It therefore follows that good judgment must be exercised in regard to placing the handle either in release or in running position while charging, as well as to the length of time it should

be kept in running position. In any case, the handle should be in running position when the brake-pipe pressure is within 10 pounds of the amount for which the feed-valve is adjusted. If it is not in running position at this time, overcharging of the front portion of the train is sure to result.

In many yards the trains are already charged when the locomotive is coupled to it, so that charging from zero by the locomotive is not required. In such cases, the handle should be allowed to remain in running position. However, as the brakes must be tested by applying and releasing before departure, the same care in regard to overcharging the front end of the train as just recommended should be observed when releasing. In no case of releasing brakes should the handle remain in release position for more than 15 seconds. Short trains may be charged in running position.

HANDLING THE TRAIN

47. Running Test.—With passenger trains the running test must always be made; there is no excuse for omitting it. Indeed, when the importance of such a test is realized by the engineer, he will feel obliged to use it in all cases with skill.

After the train has left a terminal and is running at a speed of about 15 miles an hour, the engineer should, without closing the throttle, make a service reduction sufficiently heavy to cause all brakes on the train to act and then slow it down against the pulling effect of the locomotive, noting meanwhile the length of the brake-valve exhaust. When it is seen that the brakes take hold as they should, he should release in the usual manner.

The running test must also be made when approaching meeting points, railroad crossings at grade, junction points, drawbridges, terminal stations, before commencing the descent of a long, heavy grade, and before getting close to any point when the brake must work to prevent disaster. The test should be made when sufficiently far away from such points to make sure that if the air brake does not respond there will yet be distance enough to bring the train to a standstill with

the hand-brakes. Just how far from the stopping point, then, that this test should be made will depend on the speed of the train, the grade, and the general condition, but in any case it should not be less than 1 mile.

Before reaching the point where the running test is to be made, the engineer should consult the air gauge so as to be sure that the maximum standard pressure is present in the brake pipe; also, at the moment that the service reduction is begun, he should note the length and the volume of the brake-pipe exhaust. These duties are important, because if other means for stopping is necessary, no time dare be wasted.

48. Running Precautions.—As the air brake is always relied on to control the motion of the train, both in service and in emergency applications, it should also be in condition to operate at its maximum efficiency every moment of the time that the train is in motion. Hence, it follows that certain precautions should be observed by the engineman while running so that he may know constantly and with certainty that the brake will respond promptly if needed.

These precautions include the frequent observance of the air gauge, so as to know whether or not the pump is maintaining the standard pressures for the road on which the train is running as well as the class of train; the careful observance of the position of the brake-valve handle, so as to see whether it is in the proper position to feed air into the brake pipe; and the observance of the position of the double-heading cock, so as to know that it is wide open, except as prescribed under the rule for double-heading, and not partly closed or accidentally shut.

In all brake applications, the length of the brake-pipe exhaust as well as its volume of sound should be carefully observed as soon as the reduction is commenced, so as to know whether it corresponds to the length of the train. While brakes are supposed to be released, as is the case while running, it is important that the handle of both brake valves be carried in running position, to avoid the possibility of locomotive brakes creeping on. In the case of double-heading or of helper engine, the enginemen of both engines should always know whether the proper

brake-pipe pressure is being carried; also, when the controlling engineer is making applications, the engineer of the second engine should know whether the proper reduction in brake-pipe pressure is being made.

49. Service Stops for Both Long and Short Trains. The two-application method of stopping a train at any designated stopping point, with either long or short passenger trains, is preferable to the one-application method, because, as a rule, better time and smoother and more accurate stops can be made with it. However, with short passenger trains, good rail, and the exercise of excellent judgment, the one-application method may be used with equally as good results. When the one-application method is employed, say on trains of 6 or fewer than 6 cars, the aim should be to make the stop with not more than a 25-pound service reduction, and then, just before coming to a dead stop, to release the brakes in time to allow the trucks, which are sure to be tilted, to right themselves, and in this way prevent the disagreeable back lurch so annoying to passengers. But, as just remarked, the two-application method will usually be found smoother and more accurate; also, by using it, there is far less danger of causing damage to wheels by sliding them, and much less time is consumed in making the stop.

In stopping trains by the two-application method, the engineer should, if time is fast, permit the train to approach as near to the stopping point as his judgment dictates. He should then make a heavy service reduction, such as would be necessary to bring the train to a speed of 12 or 15 miles an hour. Next, he should release by moving the handle to release position momentarily; then back to running position for a second, to drop the locomotive cylinder pressure to 5 or 6 pounds; and, finally, depending on the time and other circumstances, either to lap or to service position, completing the stop with a light cylinder pressure.

The object of the two-application method is to permit a high rate of speed to be maintained up to a point as close to the station as circumstances and good judgment will warrant. Then, if the speed is high, a heavy continuous service applica-

tion may be made without danger of shock to the train, or of sliding the wheels. The release at slow speed permits all tilted trucks to straighten up, and any wheel that may possibly be sliding to commence rotating again. The final application, which need only be a light one, may be held on until the train stops.

After a train has been stopped in this manner, the brakes may be released in the usual way; that is, by placing the handle in release for 4 or 5 seconds and then returning it to running position. If, however, a water-tank stop or a stop on down grade is made, the handle may be returned to holding position instead of to running position, and held there until ready to start, when, of course, it must be placed in running position.

50. Stopping Short or Running By.—If the engineer in handling a long passenger train finds that the train is going to stop short, he should release the brake in the usual manner and permit the locomotive cylinder pressure to escape slowly. In this way he will avoid the possibility of a jerk from the rear, which might take place if the rear brakes release slowly. If he finds that it is necessary to use steam to move up to the desired spot, he should not use the throttle until he is sure that all rear brakes have had time to release fully.

In all cases of running by stations, the brakes should be held applied until just about to come to a standstill, when they may be released in the usual manner. In such cases, the train usually has to be backed up to unload passengers and baggage. This, of course, makes it necessary to apply the brake with the train moving backwards so as to stop. Under such circumstances, the brake should be applied lightly and gradually in order to adjust slack as gently as possible, and then held applied until the train stops. In making brake applications while backing, it will sometimes help in the smoothness with which the slack is adjusted if the locomotive brakes are prevented from applying hard by moving the handle of the independent brake valve to release position and holding it there until after the car brakes are well on.

51. Stops on Grades.—All service stops on grades should be made with the two-application method. After the final release, which should not be made until after the train stops, unless the grade is very heavy and requires the train brakes to help hold the train while standing at the station, the handle should be moved back to holding position while there is still sufficient cylinder pressure, so as to prevent the train from moving, and it should be kept there until ready to start, when it must be placed in running position. If, after coming back to holding position, there is not sufficient cylinder pressure left in the locomotive brake cylinders to hold the train, it will be necessary to add enough with the independent brake valve.

52. Quick Action During Service Reduction.—Quick action during a service reduction, or undesired quick action, as it is generally called, is not only annoying but sometimes does great damage. It is due to a defective condition of one or possibly more than one of the triples in the train. Such triples may give trouble at each service application, or only occasionally during the trip. However, in passenger service, no triple should ever be allowed to leave a terminal in a defective condition. Instead, the troublesome triple should be located and removed. To locate a defective triple, the assistance of observers stationed along the train is required. When they are in their positions, the engineer, after charging the train to full pressure, should make a service reduction not to exceed 5 pounds. Any brake that fails to apply can then be noted by the observers. A further reduction of not more than 3 pounds should next be made, and the observers should note whether or not the piston that has failed to move on the previous reduction applies with a quick action. If it does, this brake should be cut out. The test should be repeated after the system has been fully charged to maximum pressure, and there has been sufficient time for the pressure to equalize thoroughly throughout the train. At terminals, of course, the defective triple should be replaced by one in perfect condition.

If undesired quick action occurs while the train is on the road, the cut-out cock should be closed and the drain cock on

the auxiliary reservoir opened; also, the engineman should be notified of this procedure.

When testing for defective triples that give undesired quick action, it is very important to have the maximum brake-pipe pressure in the brake pipe and the auxiliaries at the commencement of each test. If it is found impossible to locate the defective triple within a reasonable period of time, the train may proceed with the standard brake-pipe pressure. When making service stops under such circumstances, however, the two-application method should be employed. The first application should be made in the emergency position when speed is high. The second, which always follows close on the release of the first application, can be made in service with a greatly reduced brake-pipe pressure and hence without likelihood of undesired quick action.

53. Emergency Stops.—Emergency applications are required when it is necessary to stop the train to prevent loss of both life and property. In such cases, the handle of the brake valve should always be placed quickly in emergency position the instant the emergency appears and kept there until the train stops or the danger is passed. However, in the case of long passenger trains, if the danger passes before the train comes to a full stop and it is desired to proceed, the brakes may be released in the manner already explained. However, the locomotive cylinder pressure should not be allowed to escape entirely until it is certain that the rear brakes have released, when the handle of the brake valve may be moved to running position and the throttle opened gradually.

If an emergency application is made and the brake-pipe pressure entirely depleted, reducing the speed to 20 miles an hour or less when the danger disappears, it is better with long trains to stop before making the release. In all cases of emergency, sand should be applied to the rails as soon as the handle of the brake valve is in emergency position.

54. Backing Trains With Tail-Hose.—In order to move passenger trains from yards to terminal stations, or from the

main line to branch stations at the end of short branches, it is necessary in many instances to back them long distances. In such cases, the brakes should be operated from the rear of the train by means of a tail-hose that is equipped with a valve that can be opened and closed as gradually as desired by the operator. Before commencing to back the train, the engineer should charge the brake system in the usual manner. The brakes should also be tested both from the brake valves on the engine and from the tail-hose valve at the rear of the train, so as to make sure that all of them can be applied and released from either end of the train.

No hard-and-fast rule can be made as to where the handle of the brake valve on the engine should be carried while backing the train. The practice most generally adopted is to carry it in running position continuously until the terminal is reached. In this way, all the responsibility for the safe handling of the train is placed on the man that manipulates the tail-hose exhaust valve. However, the engineer should be as vigilant as circumstances will permit. In the event of an emergency application, he should quickly lap the brake-valve handle to prevent possibility of release. After the train stops or after he is signaled from the rear to release, he should release in the usual manner, and then return the handle to running position.

55. Wheel Sliding.—In passenger service, the injudicious use of sand often cuts the wheels so badly from sliding that they must be removed. It is important to remember that modern passenger equipment is much heavier than that built a few years ago; hence, a wheel does not have to slide so far as formerly to become flat.

To prevent injurious wheel sliding, the engineman handling any passenger train except one with the L triple equipment should practice the two-application method of making all stops except emergency stops. This method, as already explained, requires high cylinder pressure while the speed of the train is high, which is the time that the wheels are least likely to slide, and the first release takes place at the time that the speed is considerably reduced, when the wheels are most likely to pick

up; also, the second application is a comparatively light one—one that will not cause the wheels to slide although the speed is much slower than when the first application was made.

If the condition of the rail is such that sand must be used to assist in making the stop and to prevent wheel sliding, it should be dropped under the entire length of the train before commencing to use the brake. The reason for this should be well understood. It is because of the careless and unskilful use of sand in stopping that many wheels are badly damaged. If the brake is applied a little later than it should be in order to make the stop within the distance available, it is likely to be applied full; then, when the stopping point is approached, if it is thought that the train is going to run by, there is a strong temptation on the part of the engineer to drop sand, because if sand is used it may prevent the train from running by. At the same time, if there happens to be one or more pair of wheels sliding while sand is dropped, they will be cut badly, and in a very short distance. In all cases of emergency, however, wheels should not be considered, and sand should be dropped just as soon as possible after the brake valve is placed in emergency position.

If, in starting, the train drags and the drivers slip considerably, the engineer sometimes makes the mistake of dropping sand to prevent the slipping while at the same time they work the engine in the corner with full throttle. When a train starts unusually hard, a stuck brake and a sliding wheel are usually the cause. Therefore, in a case of this kind, the proper thing to do is to manipulate the brake valve in the manner recommended for releasing brakes. If sand is required, only sufficient should be dropped to prevent the drivers from slipping. In such a case, using sand too freely will of itself cause the train to pull hard.

56. Stuck Brakes.—Brakes that do not release promptly or that remain applied for some time after the other brakes have released are a serious annoyance in train handling. They not only cause damage to wheels but are often responsible for break-in-twos.

There are a number of causes for sticking brakes. Some stuck brakes are attributed to the manner in which the brake valve is handled on the engine; some to the condition of the triple valve; some to the condition of the feed-valve; some to the condition of the foundation brake gear; some to the piston travel; and so on. The pressure retainers are also responsible for the non-release of brakes in some cases, and the slack adjuster sometimes causes brakes to drag because of taking up the slack too close.

57. The careful observance of the proper method of releasing brakes will almost invariably prevent the sticking of brakes so far as the air-brake equipment proper is concerned. On trains of average length, a service reduction of at least 10 to 12 pounds should be made before the release is attempted. This reduction need not be made continuous in all cases, but the total reduction before attempting the release should be not less than this amount. The reason for having the brake-pipe reduction not less than 10 pounds before commencing the release is to provide a larger difference between the main-reservoir and the brake-pipe pressure, so that when the handle is placed in release position the wave effect will be more pronounced throughout the whole length of the brake pipe, and, therefore, more effective in moving the triple piston to release position.

When releasing, the engineer should place the handle of the automatic brake valve in release position for 4 or 5 seconds—no longer—and then return it to running position. After about 3 seconds he should move it quickly to release and immediately back to running, especially if the train is unusually long. This latter movement will release all brakes in the front of the train that may have reapplied on account of lightly overcharging.

58. If triple valves become defective on account of excessive packing-ring leakage or their condition is bad on account of dirt and gum, they will not respond promptly to slight variations in brake-pipe and auxiliary-reservoir pressures. Therefore, as it frequently happens, especially in long trains, that the rise in brake-pipe pressure is comparatively slow, such triples are likely to remain in the applied position and thus prevent

the release of the brake. Such triples should be removed from the car at the first inspection point and other triples in perfect condition put in their places. The removed triples should then be sent to the repair shop for overhauling and for testing on the repair-test rack.

The feed-valve will cause the brakes to stick if it becomes sluggish in its action or if its supply passage becomes gummed with oil or plugged up with dirt; that is, if it does not respond to slight variations in brake-pipe pressure. The feed-valve must supply the brake pipe with air promptly and in generous volume up to the desired pressure and then maintain it at that pressure without variation of over $1\frac{1}{2}$ pounds. If the feed-valve allows the pressure to fluctuate or vary widely, then, of course, the brakes might creep on and stick, unless, in such cases, the brake-valve handle is thrown to release position for an instant. Therefore, to avoid stuck brakes from this cause, the feed-valve should be maintained in first-class condition.

A defective foundation brake gear is sometimes responsible for stuck brakes. For instance, a loose bolt or a loose hanger chain may wedge between the brake beam and sand plank of the foundation brake gear, or one of its levers may become fouled in some other manner. In such cases the shoes cannot fall away from the wheels, even if the air does exhaust properly from the brake cylinder. As a result, the brake will stick on one or more pair of wheels, depending, of course, on the nature of the brake-gear defect.

Short piston travel can, and often does, cause the brakes to hang for some time, especially on long trains. Since short piston travel causes the auxiliary and brake cylinder to equalize higher than the average pressure, brakes having this short piston travel fail to release until the brake-pipe pressure comes up to a point sufficiently high to force the triple to release position. As this point is considerably higher than that for the other triples in all full-service applications, it follows that the brake will be longer in coming off and hence may be considered as sticking. The remedy for this, of course, is to adjust the piston travel to the proper length. It is also advisable to avoid the practice of making over reductions on service applications.

Emergency valves that occasionally stick open will prevent brakes from releasing. The remedy in such cases is to close the cut-out cock and then open it quickly, so that any foreign substance on the valve seat that is causing the leakage may be blown off. If this does not effect a remedy, the cut-out cock should be closed and the auxiliary bleed cock opened.

If hand-brakes are not entirely released, the brakes are on this account sometimes said to stick.

59. Bleeding Off Brakes.—In passenger service, all brakes should release from the engine; and they can be so released unless they are improperly manipulated or are in a defective condition. If difficulty is experienced in releasing brakes or if they stick, bleeding off should never be resorted to for the purpose of releasing or getting out of the difficulty, because it is a dangerous practice. The better plan is to investigate and remedy the defect that may be causing the brake to refuse to release.

If it is necessary to cut out the brake on a car because of the failure of some part of the foundation brake gear or because of broken or defective air-brake apparatus, the cut-out cock should be closed and the release cock on the auxiliary opened and left open until the terminal is reached. The engineer of the train should be informed about any brake that is cut out, and at the terminal the matter should be reported to the proper authorities for attention.

60. Break-in-Twos.—Although more or less trouble from breaking in two has always been experienced with both passenger and freight trains, it is becoming a more serious matter with the modern heavy and long trains of both classes. To prevent this dangerous, expensive, and annoying occurrence should be the aim of all persons concerned in the safe operation of trains over the road. With passenger trains, a break-in-two should never be allowed to occur, because it is attended not only by damage to equipment and delay to traffic, but by great danger of injury to passengers as well as loss of life.

Since the braking power of the passenger equipment should be, and generally is, such as to make it as nearly uniform as

possible, the retardation of each vehicle during a brake application will be the same; hence, the strain on the couplers is reduced to a minimum. This uniformity of retardation is largely or wholly due to the designs of the foundation brake gear, and the further freedom from the danger of breaking in two is due to the adoption of a strong and suitable draft gear.

The brake and the throttle are in the hands of the engineer, and on the manner in which these are handled depends the smooth running of the train. Service application of the brakes must be made as prescribed in the rules. However, when a release is to be made, the speed at that moment must be considered. If it is slow, the holding feature of the H-6 brake valve should be intelligently employed, so that the slack may not run out hard, and that no shock at the rear will be caused by retaining too little pressure in the locomotive brake cylinders. If the release is made while the train is in motion and it is desired not to stop, the throttle should be opened gradually after sufficient time has elapsed for all the rear brakes to release and the slack taken out gently. Then, in the event of a rear brake not having released, the strain brought to bear on the couplers will not be sufficiently violent to cause them to part. Also, sufficient time should always be allowed between the release and the reapplication of the brakes to prevent those on the head part of the train from coming off and then reapplying before the rear has released. If this precaution is not observed, the train will stretch and then suddenly close the slack, which will be followed by another violent stretch from the rear.

61. Picking up Cars.—When picking up passenger equipment the engineer should stop the engine or the train about 10 feet from the cars to be picked up and then move it slowly in making the coupling. After the cars have been coupled to the train, care should be taken to see that both the brake and the signal hose are properly coupled together and that all angle cocks and stop-cocks except the rear one on the rear car are opened. The rear angle cock on the car coupled to those picked up should then be opened gradually until the air is heard to flow into the empty hose and brake pipe. After a few seconds, this

angle cock should be opened wide and the auxiliaries permitted to charge properly to the required pressure for testing the brakes, which, if the high-speed brake is used, is usually the maximum brake-pipe pressure, or 110 pounds. When charging is completed and all hand-brakes are properly released, the brakes should be tested to make sure that they will operate throughout as desired.

The reason for opening the angle cock gradually on the car ahead of the one picked up is to prevent an emergency application of the brakes and a consequent waste of air and of the time necessary to pump the air back. While the auxiliaries are charging, it is well to see that all release valves and bleed cocks are closed and that no bad leaks exist.

When two train sections that are already charged are coupled together, care should be taken to prevent an emergency application on the rear section. Such an application can be prevented after coupling the hose by first opening gradually the angle cock nearest the locomotive and then gradually opening the other angle cock.

62. Setting Out a Car.—A car that is to be set out or left on a side track should not be detached from the engine or train until it is moved to the place where it is to be left standing. When in its proper place the angle cocks on its brake pipe, also the one on the rear of the car ahead, should be closed, the hose parted by hand, the bleed cock on the auxiliary reservoir opened and left open, and the hand-brake applied with sufficient force to prevent the car from moving of its own accord. A car that is to be left standing on a grade or an incline, must by all means have its hand-brake applied, but care should always be taken to have the air brake entirely released before setting the hand-brake.

When a train from which a car has been set out is recoupled, it is necessary to make sure that all angle cocks except the rear one are wide open and that the system is properly charged; also the required test of the brake should be made before proceeding.

TRAINS WITH L N EQUIPMENT

CHARGING THE TRAIN—MIXED L AND P TRIPLES

63. If a train is only partly equipped with L triples, it is customary to cut out the supplementary reservoir, so that only the auxiliary will have to be charged. Hence, in such cases, the charging of all auxiliaries in the train will be uniform in regard to time and pressure, and the amount of time required will be about the same as if all the triples were of the P type.

If the auxiliaries and supplementary reservoirs of a train that is wholly equipped with L valves have to be charged from zero to maximum pressure, more time, of course, will be required than if the auxiliaries alone were to be charged; but after both the supplementary and the auxiliary are fully charged, the brakes require no more air for this operation than the brakes on a train equipped with the P triple. Hence, the auxiliaries regain their maximum pressure in recharging just as quickly as they would with P valves alone. Nevertheless, sight should not be lost of the following facts: With L valves and supplementaries cut in, the auxiliaries regain very quickly a large percentage of the pressure that is reduced by the flow of auxiliary air into the brake cylinders during the application of the brakes; also, after the release is made, by reason of the supplementary and the auxiliaries combining and equalizing, the remaining increase of pressure is obtained comparatively slow, because the air from the brake pipe must charge the auxiliary and the supplementary reservoirs simultaneously.

HANDLING THE TRAIN

64. To handle trains with the L N equipment so as to get the best results in service, the engineer should make the initial reduction, while the speed of the train is high, at a sufficient distance from the stopping point to bring the train to a standstill some distance short of this point, if it were desired to do so; then, as circumstances require, he should commence to graduate

the brake off by moving the handle of the brake valve from lap to running and back for each graduation, so as to bring the train to a stop at the desired spot, aiming to have the cylinder pressure at the instant of stopping reduced to such a point that the disagreeable lurch that would occur if the cylinder pressure were high at the instant of stopping will not take place.

From the preceding statement it will be seen that the object aimed at is to get the brakes on just as hard as the speed of the train will warrant at the time that the initial reduction or the application is made, and then to commence graduating off the instant that it is seen that the stop will be short of the mark unless cylinder pressure is reduced, aiming always to complete the stop with one application and a light final cylinder pressure.

When graduating off the brakes, the handle of the brake valve should be moved to running position only for an instant and then back to lap. The reason for this should be clear from the explanation of the construction and operation of the L triple. The method of handling the brake valve applies to both long and short trains. Experience, however, will indicate clearly whether or not it can be improved.

An important consideration in handling a train having L N equipment is to avoid overcharging the brake pipe. If this pipe is overcharged, trouble will be experienced, as the brakes are liable to creep on when it is desired that they remain released.

65. Service Stops and Releasing.—On all passenger trains where the running time is fast, as little time should be utilized in making service stops as is consistent with good braking. Therefore, a high initial service reduction should be made when a service stop is required, so that the speed of the train may be quickly reduced and brought down to a rate of stopping, or of retardation that, if continued, would cause the train to stop short of the desired mark; then the brake cylinder pressure should be graduated down so that the train will come to the desired spot and stop with a light pressure retained in the brake cylinders. After the train has stopped, unless it happens to be on a down grade, the handle should be placed in

release for 4 or 5 seconds and then returned to running position. When making the complete release the engineer should be careful not to overcharge the brake pipe; if this happens, trouble will be experienced by the brakes going on when it is desired that they remain released.

In making close, accurate stops, the engineer should remember that the L triple will graduate the brake on as well as off. Hence, if it is found in a service stop that the cylinder pressure has been graduated off too much to bring the train to a stop at the desired spot, a light service reduction, say one just sufficiently heavy to produce the required brake-cylinder pressure to bring the train to a final stop, may be made.

66. Emergency Stops.—Emergency stops with trains having the L N equipment are made in the same manner as emergency stops with trains equipped with any other type of triple valve. In other words, when an emergency arises, the brake-valve handle should be quickly placed in emergency position and left there until the train stops or the danger is passed. After this, if it is desired to release the brakes immediately, the handle should be placed in release for 5 to 6 seconds and then returned to running position. The rails should be sanded throughout the stop, as with the other equipments. It is well to remember that in emergency applications a very high cylinder pressure is developed and that the auxiliary pressure does not drop much. Thus, if the handle is left in release too long during release, overcharging of the brake pipe may result. In such cases, this would cause the triple to reapply the brakes and produce annoyances from graduating the brakes on when they should remain entirely released.

67. Trains on Grades.—When about to descend a long, steep grade with a train having the L N equipment, the brakes should be thoroughly tested, just as with any other type of triple. The auxiliaries and supplementary reservoirs should also be fully charged before commencing the descent, and the handle on the pressure-retaining valves should be turned up so as to assist in the safe handling of the trains. However, for

moderate grades that are 20 miles or less in length, pressure retainers are not needed.

While the train is descending the grade, the method of manipulating the brakes recommended for trains having the type P triple should be observed, so that advantage may be taken of curves and let-ups for recharging purposes. The train should not be allowed to gather too much headway before commencing the application of the brakes; also, the brake applications should be as light and as frequent as they can possibly be made, in order to maintain as uniform a rate of speed as possible throughout the entire descent, and also to maintain as high a general brake-pipe and auxiliary-reservoir pressure as possible.

When making the release for the purposes of recharging and keeping the train moving at the desired speed, the brake-valve handle should be placed in release position and left there for 4 or 5 seconds and then returned to running position.

68. Bleeding Off a Brake.—When the locomotive is detached from a train having the L N equipment, or when the brake pipe is accidentally overcharged, it will be necessary to release the brakes by means of the drain, or release, cock. In the case of an overcharge brake pipe, the brakes will apply and it will be impossible to release them from the locomotive and keep them released with the brake-valve handle in running position. Hence, if the train is in motion the brake-valve handle should be carried in release position until the next stop is made, when the brake-pipe pressure should be reduced to 60 pounds by placing the brake-valve handle in service position. The drain cock on the supplementary reservoir should then be opened and kept open for about 10 seconds. This will reduce the supplementary-reservoir pressure to a point where the brakes may be released from the locomotive in the usual manner. It is very important in handling L N equipment to avoid the overcharging of the brake pipe.

If it is desired to release the brake on one or more cars when the locomotive is detached, the drain cock on the auxiliary should be opened and held open until the air commences to escape from the brake cylinder. It should then be closed and

note made of whether the brake releases entirely or not. If the brake does not release entirely and stay so, the auxiliary drain cock should again be opened and, as before, closed the instant that the brake-cylinder air commences to escape at the exhaust port of the triple. This operation should be repeated until the brake remains released.

It is well to remember that when releasing by means of the auxiliary drain cock, the supplementary-reservoir air commences to feed back into the auxiliary the instant that the triple slide valve reaches release position, and that this air will increase the pressure therein and cause the triple to return to graduated-release lap position or to service-application position; hence, the necessity for opening and closing the drain cock a second or a third time, or until the brake-pipe, auxiliary-reservoir, and supplementary-reservoir pressures are equalized, with the triple piston finally in release position. To allow the drain cock to remain open longer than is necessary to do this would reduce both the auxiliary-reservoir and the supplementary-reservoir pressure below that remaining in the brake pipe, and then a reduction in brake-pipe pressure caused by the brake-pipe air feeding into the auxiliary would begin and possibly cause some of the brakes on the other cars attached to commence to apply.

INDEX

NOTE.—In this volume, each Section is complete in itself and has a number. This number is printed at the top of every page of the Section in the headline opposite the page number, and to distinguish the Section number from the page number, the Section number is preceded by a section mark (§). In order to find a reference, glance along the inside edges of the headlines until the desired Section number is found, then along the page numbers of that Section until the desired page is found. Thus, to find the reference "Adhesion, §5, p18," turn to the Section marked §5, then to page 18 of that Section.

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